Effects of contextual factors on the outcomes of household energy use interventions

Tuija Kajoskoski
University of Helsinki
Faculty of Social Sciences
Social and Public Policy
Master’s thesis
October 2019

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tiedekunta – Fakultet – Faculty Faculty of Social Sciences		Koulutusohjelma – Utbildingsprogram – Degree Programme Master's programme in Social Sciences
Tekijä – Författare – Author Tuija Stina Orvokki Kajoskoski		
Työn nimi – Arbetets titel – Title Effects of contextual factors on the outcomes of household energy use interventions		
Oppiaine/Opintosuunta – Läroämne/Studieinriktning – Subject/Study track Social and Public Policy		
Työn laji – Arbetets art – Level Master's thesis	Aika – Datum – Month and year October 2019	Sivumäärä – Sidoantal – Number of pages 69

Tiivistelmä – Referat – Abstract

Households account for a significant proportion of final energy consumption in Europe. Household energy consumption has been researched intensively and intervention studies aiming at changing energy behaviour have been popular. Previous intervention studies have mainly been concentrating on individual behaviour, and research analysing the role of contextual factors has been very limited. The aim of the thesis is to study the effects of geographical and cultural, material and institutional, and socioeconomic and demographic contexts on the outcomes of household energy use interventions.

The data used in this thesis was collected in a European research project "ENERGISE", in which interventions on two energy intensive household practices, space heating and laundry washing, were carried out. The data included 306 households from eight European countries: Switzerland, Germany, Denmark, the Netherlands, Finland, Hungary, Ireland and the UK. The data was analysed using the following methods: one-way ANOVA, independent samples t-test, Pearson's correlation, and multiple linear regression. The following independent variables were tested: country, building type, baseline consumption levels, education level, employment status, family size, and age. The analyses were conducted in two phases. In the first phase, the main effects of the independent variables were tested. In the second phase, multiple regression models were built based on the results from the first phase.

The intervention outcomes differ between some of the geographical contexts. Temperatures are reduced the most in Switzerland, Germany and the Netherlands, and laundry cycles are reduced more in Denmark than in other countries during the interventions. Higher baseline consumption levels are connected to higher reductions in both household practices. Families with five or more persons reduce the room temperatures and laundry cycles less than smaller families. Households with contact person aged 55-64 reduce laundry cycles the least. Building type, contact person education level and contact person employment status are not connected to the intervention outcomes.

The results confirm observations from previous studies, that context may significantly affect the successfulness of energy behaviour interventions and therefore it should be carefully considered in planning interventions. The results also suggest that different energy practices are likely to be affected by different sets of contextual factors. The thesis shows that conducting cross-national comparative research is challenging and it requires careful planning throughout the research process.

Avainsanat – Nyckelord – Keywords
Context, interventions, energy, households, comparative research

Ohjaaja tai ohjaajat – Handledare – Supervisor or supervisors
Senja Laakso, Arho Toikka

Säilytyspaikka – Förvaringställe – Where deposited

Muita tietoja – Övriga uppgifter – Additional information

HELSINGIN YLIOPISTO
HELSINGFORS UNIVERSITET
UNIVERSITY OF HELSINKI

Tiedekunta – Fakultet – Faculty Valtiotieteellinen tiedekunta		Koulutusohjelma – Utbildingsprogram – Degree Programme Sosiaalitieteiden maisteriohjelma
Tekijä – Författare – Author Tuija Stina Orvokki Kajoskoski		
Työn nimi – Arbetets titel – Title Kontekstuaalisten tekijöiden vaikutus kotitalouksien energiainterventioiden tuloksiin		
Oppiaine/Opintosuunta – Läroämne/Studieinriktning – Subject/Study track Yhteiskuntapolitiikka		
Työn laji – Arbetets art – Level Maisterintutkielma	Aika – Datum – Month and year Lokakuu 2019	Sivumäärä – Sidoantal – Number of pages 69

Tiivistelmä – Referat – Abstract

Kotitaloudet kuluttavat huomattavan määrän loppuenergiasta Euroopassa. Kotitalouksien energian kulutusta on tutkittu intensiivisesti ja käyttäytymisen muutokseen tähtäävät interventiot ovat olleet suosittuja. Aikaisemmat interventiotutkimukset ovat suurelta osin keskittyneet yksilön käyttäytymiseen ja kontekstuaalisten tekijöiden roolia tarkastelevia tutkimuksia on tehty vain vähän. Tämän tutkielman tarkoituksena on tarkastella maantieteellisen ja kulttuurisen, materiaalisen ja institutionaalisen ja sosioekonomisen ja demografisen kontekstin yhteyttä interventioiden tuloksiin.

Tutkielmassa käytetty data kerättiin eurooppalaisessa ENERGISE-tutkimushankkeessa, jossa toteutettiin interventiot kahdessa energiaintensiivisessä kotitalouskäytännössä, lämmityksessä ja pyykinpesussa. Aineistossa oli mukana 306 kotitaloutta kahdeksasta maasta: Sveitsistä, Saksasta, Tanskasta, Hollannista, Suomesta, Unkarista, Irlannista ja Iso-Britanniasta. Aineiston analysoinnissa käytettiin seuraavia metodeja: yksisuuntainen ANOVA, riippumattomien otosten t-testi, Pearsonin korrelaatiokerroin ja lineaarinen regressio. Selittävinä muuttujina käytettiin maata, rakennustyyppiä, seurantajakson kulutusta, koulutusta, ammattiasemaa, perhekokoa ja ikää. Analyysi suoritettiin kaksivaiheisesti. Ensimmäisessä vaiheessa tarkasteltiin kunkin riippumattomat muuttujan päävaikutuksia riippuviin muuttujiin. Toisessa vaiheessa rakennettiin usean selittäjän lineaariset regressiomallit perustuen ensimmäisen vaiheen tuloksiin.

Intervention tuloksissa havaitaan eroja maiden välillä. Interventioiden aikana lämpötiloja alennetaan eniten Sveitsissä, Saksassa ja Hollannissa, ja pyykinpesua vähennetään enemmän Tanskassa kuin muissa maissa. Korkeammat lämpötilat ja pesumäärät seurantajaksolla ovat yhteydessä suurempiin vähennyksiin haastejaksoilla. Perheet, joissa on viisi tai enemmän henkilöä vähentävät lämpötiloja ja pyykinpesua vähemmän kuin pienet perheet. Rakennuksen tyyppi, kontaktihenkilön koulutustaso ja kontaktihenkilön ammattiasema eivät ole yhteydessä interventioiden tuloksiin.

Tutkielman tulokset vahvistavat aiemmassa tutkimuksessa tehtyjä havaintoja siitä, että kontekstuaaliset tekijät vaikuttavat interventiotutkimusten tuloksiin, ja siksi niihin pitäisi kiinnittää erityistä huomiota interventioiden suunnittelussa. Tulokset myös osoittavat, että erilaiset tekijät voivat olla yhteydessä eri energiakäytäntöihin. Tutkielma osoittaa lisäksi, että maavertailujen tekeminen on haastavaa ja vaatii huolellista suunnittelua kaikissa tutkimuksen vaiheissa.

Avainsanat – Nyckelord – Keywords
Konteksti, interventiot, energia, kotitaloudet, vertaileva tutkimus

Ohjaaja tai ohjaajat – Handledare – Supervisor or supervisors
Senja Laakso, Arho Toikka

Säilytyspaikka – Förvaringställe – Where deposited

Muita tietoja – Övriga uppgifter – Additional information

Contents

List of tables

List of figures

1. Introduction

Climate change has been increasingly referred to as climate crisis, which reflects the urgency of action needed and the future impacts it will have on humanity. The pressing need to reduce greenhouse gas emissions central component of effective climate change mitigation. Household consumption is responsible for roughly 72% of global carbon emissions (Druckman & Jackson 2016), and 25% of final energy consumption (Eurostat 2018). In Europe, the largest amount of residential energy is used for space heating, which accounts for 64.1% of total residential sector's energy consumption. Water heating accounts for 14.5% and lighting and appliances 13.8%, while cooking (5.4%), space cooling (0.3%) and other end uses (1.3%) account for the rest (Eurostat 2018). Households are, thus, an important group of emitters, and while accounting for a significant amount of final energy consumption, households hold potential for substantial reductions.

This thesis focuses on studying change in household energy consumption behaviour resulting from an intervention in two energy intensive household practices: space heating and laundry washing. Taking a cross-national and comparative perspective, I analyse a number of factors related to national and cultural context, material and institutional context, and socioeconomic and demographic context to evaluate if they are connected to the reductions households achieved during the interventions. This thesis contributes to the gap in research acknowledged by several scholars (e.g. Heiskanen et al. 2019a; Clayton et al. 2016) of bringing the role of context in intervention studies to the centre of the research. This thesis will also contribute to the low number of international comparative research studies in the field of energy behaviour change.

Household energy consumption has been studied intensively in recent decades. Researchers from different disciplines and from a variety of theoretical perspectives have been interested in factors shaping energy consumption. Traditionally, energy behaviour studies have been concentrating on individual behaviour, using in particular economic or psychological behaviour models (Maréchal 2010; Brandon and Lewis 1999). Economic theory is based on assumptions of rational calculations in relation to action (Reckwitz 2002). One of the most significant psychological behaviour models is the theory of planned behaviour (Ajzen 1991), in which it is argued that attitudes toward the behaviour and subjective norms affect intentions to behave in a certain way, which then affects the actual behaviour. More recently, there has been a growing interest in studying consumption from less individual-cantered perspectives, such as theories of social practices (Warde 2005; Shove 2003; Rau & Grealis 2017).

Intervention studies have been central in efforts to change energy consumption behaviour. Different intervention strategies (or ‘mechanisms’) have been evaluated and compared (e.g. Abrahamse et al. 2005) to generate knowledge about their effectiveness. Intervention strategy research, taking the mechanisms as the central piece of the analysis, has been criticized for ignoring the context in which the different interventions take place. Similarly, studies based on psychological theories typically treat interventions as universal and context-independent. (Heiskanen et al. 2019a, 8.) Other scholars have also expressed the need to consider contextual factors in sustainable behaviour intervention design. Šćepanović et al. (2017, 1146), for instance, argue that the successfulness of an intervention is very much context dependent. Despite the vast number of intervention studies made, very few have engaged in comparing factors external to the intervention design, such as socio-economical characteristics, or geographical context. Quantitative and comparative studies on intervention outcomes are rare, as most intervention studies concentrate on a single country or a single location, or two or three countries or areas within one country. There is, however, evidence suggesting that context plays a significant role in intervention outcomes, and as Heiskanen et al. (2018, 2019a) argue, transferability of interventions is an important issue to be addressed, if broader sustainability transformations and ecological validity is to be achieved.

My thesis explores the ways in which contextual factors are connected to behaviour change outcomes in a multinational household energy intervention study. The intervention is called ENERGISE, an EU-funded Horizon 2020 project conducted in eight European countries. ENERGISE studied household energy consumption practices, and aimed at achieving greater understanding of social and cultural influences on energy use by challenging households to reduce their indoor temperature and laundry cycles during a four-week challenge period (Heiskanen et al. 2018, 12). In total 306 households from eight European countries participated in the research initiative. In each country, two types of initiatives were carried out: one that had individual households changing their practices and reducing energy use, and another where households additionally shared their thoughts and activities within communities (Laakso et al. 2019).

The structure of the thesis is as follows. In chapter two, I will present findings from previous literature on household energy consumption. I discuss some theoretical perspectives from which domestic energy consumption and interventions have been studied, how context has been defined in relation to energy interventions, and what findings previous studies have made about the role of context in household energy consumption and interventions. In chapter three, I first introduce the ENERGISE research project in more detail, and after that explain the data collection process, the analytical methods I used. I present the results from my analyses in chapter five, discuss the findings and the reliability of the results in chapter six, and provide final conclusions in chapter seven.

2. Literature review

Household energy consumption has been a popular research topic for decades, and it has been studied from a multitude of research traditions. Theories based on individual behaviour have been dominant in energy consumption research, but recently there has been an increasing interest in research taking a wider perspective on energy consumption behaviour, examples being the practice based view on studying consumption (Warde 2005; Shove, Pantzar & Watson 2012) and the energy cultures framework (Stephenson et al. 2015). Despite the change in perspective and the recognition of a wider perspective on energy consumption, there still seems to be a theoretical gap in recognizing the influence of contextual factors.

The purpose of this chapter is to take a theoretical view to household energy consumption by first discussing some of the theoretical perspectives from which the household energy consumption has been previously studied. After that, I will discuss the concept of *context* in relation to household energy interventions, and how it has been defined in previous studies. Drawing from that literature, I then provide a categorization of contextual factors I find relevant to this study, and use that categorization in the thesis as a conceptual framework. Lastly, I present findings from previous research of the relevance of contextual factors on domestic energy intervention outcomes.

2.1 Theoretical perspectives in household energy consumption research

Traditionally, energy behaviour studies have concentrated on individual behaviour, using in particular economic or psychological behaviour models (Maréchal 2010; Brandon and Lewis 1999). Economic theory is based on assumptions of rational calculations in relation to action (Reckwitz 2002). From psychological behaviour models the most notable is perhaps the theory of planned behaviour (Ajzen 1991), in which attitudes toward the behaviour and subjective norms affect intentions to behave in a certain way, which then affects the actual behaviour. Energy research specifically has been interested in the connection between environmental attitudes and pro-environmental behaviour (Brandon and Lewis 1999; Pothitou et al. 2017), but the results are contradictory. Pothitou et al. (2017), for instance, found in their study that pro-environmental values were associated with domestic energy saving behaviour. Other studies (e.g. Newton & Mayer 2013) have demonstrated, quite in contrary, that there exists a so-called attitude-behaviour gap suggesting that pro-environmental attitudes and values do not necessarily lead to pro-environmental behaviour in household energy consumption. Critical views against models based solely on rationality of actors have been expressed in several studies. Maréchal (2010) and Pothitou et al. (2014) for instance, have emphasised the role of habits in human behaviour. Maréchal (2010, 1107, 1111) argues that habits work unconsciously, are context-dependent and might be hard to change. The author (2010, 1105-6) also notes that habits alone are not sufficient in analysing energy consumption behaviour, highlighting the role of structures as another barrier to energy efficiency.

Practice theories offer an alternative to theories of individual behaviour by taking ‘practices’ as the unit of analysis (Reckwitz 2002; Shove, Pantzar, & Watson, 2012, 141). Theories of social practice have been increasingly applied in the field of sustainable consumption (Warde 2005). Practice theories should not be considered one specific theory, but rather a family of social theories, and more specifically cultural theories (Reckwitz 2002, 243-44) as opposed to other social theories like the theories of ‘homo economicus’ and ‘homo sociologicus’. Practice theoretical research argues that behaviour models based primarily on rationality (such as economic theory or the theory of planned behaviour) alone are not sufficient to explain behaviour or behaviour change, because they ignore structures and collectively shared understandings of practices (Gram-Hanssen 2010, 151). In relation to consumption and practices, Warde (2005) highlights the importance of the social differentiation of practices, and their performance. According to him (pp. 138), practices are differentiated on many levels: individual performance of a practice may depend on past experience, knowledge, opportunities, or available resources for instance. Practices are not necessarily linked to specific actors, but can be performed by “long standing participants and novitiates, theorists and technicians, generalists and specialists, conservatives and radicals, visionaries and followers, the highly knowledgeable and the relatively ignorant, and the professionals and the amateur” (pp. 138). Another important consideration in relation to consumption and practices is that practices have a history, a trajectory of development, which is differentiated: it is dependent on the time, space and social context (Warde 2005, 139). Although practice theoretical research acknowledges a wider perspective on behaviour than that of theories concentrating on individuals, it does not explicitly concentrate on the context, and international comparative applications of practice theory are difficult to find.

Stephenson et al. (2010; 2015) have developed a framework called ‘energy cultures’, specifically intended to studying energy behaviour “in relation to its wider social and material context” (2015, 117). Based on their research findings Stephenson et al. (2015, 118) state that “energy behaviour is strongly influenced by the interaction between norms, practices and material culture, as well as by the external influences that form the context in which these interactions are situated”. *Norms* are shared beliefs of how to behave, and they have influence over people’s practices and their choice of technologies. Expected comfort levels, environmental concern and respect for tradition are examples of cognitive norms related to space heating (Stephenson et al. 2010, 6124). *Material culture* refers to physical elements that impact energy consumption, such as building insulation, heating devices and energy sources. *Practices* might include the analysis of the number of rooms heated, heat settings or maintenance of technologies. Practices in the energy cultures framework can be considered similar to practices in social practice theories (Stephenson et al. 2010, 6124; 2015, 219), but Stephenson et al (2015, 119) stress that there is a difference in that practices in the energy cultures framework pays more attention to infrequent actions, such as choosing material objects. Stephenson et al (2015) calls factors that have the potential to affect the norms, practices and material culture from outside as *external influencers*. They depend on the energy culture in question and the subject: for example, a tenant is subject to different external influencers than an owner in their desire to improve their apartment’s insulation (pp. 2019-20).

The theoretical perspectives discussed in this chapter vary in their focus on what is central in determining energy behaviour. Theories focusing on individuals have clearly disregarded the importance of contextual and situational factors in the analysis, while practice theoretical perspectives and the energy cultures framework have been taking a wider perspective, recognizing the historical and cultural influences in the formation of practices, and examining the social and material context around energy behaviour. However, there still seems to be a lack in research that takes context as the central focus of the analysis. I will next discuss the concept of context more thoroughly, concentrating on the relevance of context to energy consumption and energy interventions, and thereafter define the contextual perspective I will take for the present thesis.

2.2 Defining context for this thesis

Several studies have stressed the importance of contextual factors in changing energy consumption behaviour (e.g. Šćepanović et al. 2017; Heiskanen et al. 2019a). "Context" in relation to household energy consumption interventions can be defined in many ways. Šćepanović et al. (2017) define context in their study of energy interventions as "external" factors, in contrast to internal ones, such as environmental concern or trust in technology, and divides the contextual factors into four categories: physical, socioeconomic, cultural, and political and governmental (pp. 1146). With physical context, the authors refer to factors such as climatic conditions, home ownership type, and the building type. Cultural context refers to lifestyle, comfort levels and practical understanding of technology, for instance. As examples of socio-demographic context, the authors mention family relations, household size and local community and trust. The fourth category, political and institutional context, refers to e.g. governmental, institutional and political factors (pp. 1148).

In their book chapter about the role of context in energy behaviour change, Heiskanen et al. (2019a, 7) define context in energy interventions as "not only the spatial, geographical or institutional locations (such as countries and towns), but also prior set of social rules, norms, values and sets of social relationships pre-existing the introduction of the intervention". Heiskanen et al. (2019a) examine context from three perspectives. *Organizational context* refers to the spatial surroundings, such as household or workplace, and more specifically to the social dynamics in these contexts. *Geographical context* refers to locations both within and across nations. Although country comparisons are rare, the authors found studies suggesting that interventions work differently in different cultural and national contexts. The third contextual perspective in Heiskanen et al's (2019a) study is *practice as context*, which refers to practices in social contexts (such as workplace or home) shaped and influenced by norms of how to behave in certain situations.

In the ENERGISE research initiative the role of context is approached in terms of three elements: *material conditions*, *institutional conditions*, and *socially shared conventions* (Laakso & Heiskanen 2017, 9). By material conditions, the authors mean for example the type, size and age of the dwelling. Institutional conditions refer to factors such as the possibility of apartment owners to make renovations, or the physical traits of buildings such as the heat leakage from an apartment to another in apartment block buildings (Laakso & Heiskanen 2017, 12). The third factor highlighted by Laakso and Heiskanen (2017, 15), the socially shared conventions, refer to the collectively shared practices, conventions and expectations about energy consumption. Heiskanen et al. (2018, 62) use a similar categorization, but include a fourth element, geographic context, in their categorization.

As can be seen from these studies and definitions discussed above, the context in intervention studies can be defined in many ways, and the different contextual categories may be overlapping and intertwined. For example, the geographical context is overlapping with most of the other contextual categorizations. For instance, the material and institutional setting varies according to the physical location, and so do the cultural norms and habits. The political and institutional contexts of Šćepanović et al. (2017) as well as the socially shared conventions of Laakso and Heiskanen (2017) are also closely linked to geographical or national contexts.

Drawing from these definitions, and for the purpose of my thesis, I approach the concept of context in terms of three categories: 1) geographical and cultural context, 2) material and institutional context, and 3) socio-economic and demographic context. Geographical context is closely connected to cultural context, and it seems both logical and practical to combine them into one category. As discussed previously, practices have trajectories and they are connected to a certain time and a certain place, which suggests that geographical locations and cultural contexts may work as differentiating factors when evaluating energy behaviour. The cultural context, on the other hand, is connected to the socially shared conventions, or the cultural norms and habits, such as the ways energy practices are performed, or the experienced thermal comfort, as discussed by Laakso and Heiskanen (2017). The second category, material and institutional context, refers mainly to definitions made by Laakso and Heiskanen (2017), but combines elements from Šćepanović et al.'s (2017) definition of physical context, such as ownership and building type. Here, too, are linkages between the categories: especially such institutions as rules and regulations or established customs in energy billing, for example, are closely connected to national context. The third category is taken directly from Šćepanović et al. (2017), and while usually not considered as "context" in social scientific research, socioeconomic and demographic factors seem to be closely connected to many other contextual factors, such as geographical context, it seems suitable to call it a context in this thesis.

I, thus, will approach context in household energy interventions from three perspectives: geographical and cultural, material and institutional, and socioeconomic and demographic contexts. This categorization does not intend to capture all contextual factors discussed in connection to intervention studies, but it aims at being a multifaceted and explicit tool for describing the external context relevant to energy behaviour interventions specifically for the purposes of the present thesis. In addition, as stated above, these categories are overlapping to an extent. The categorisation is, therefore, just one way of understanding the different contextual factors potentially important to household energy interventions. Next, I will present findings from previous energy consumption and energy intervention studies according to these three contextual categories.

2.3 Previous research on contextual factors in household energy consumption and interventions

2.3.1 Geographical and cultural context

Geographical location and cultural context affect domestic energy consumption due to a variety of reasons. Climatic conditions, building isolation systems, cultural norms and thermal comfort are just a few examples. Although research in cross-national and cross-cultural differences in energy consumption behaviour has been quite extensive, cross-national comparisons in domestic energy interventions, as discussed in the introduction, are very rare.

Several studies (see for example Vávra et al. 2015; Sahakian and Naef 2019) have demonstrated that room temperatures vary within Europe. Vávra et al. (2015), conducted a cross-national analysis of household living room temperatures in three locations in Europe, Scotland, Germany and the Czech Republic, and found that the temperatures varied significantly between the three locations: from 18.9°C in Aberdeen in Scotland, to 20.7°C in Brandenburg in Germany to 21.7°C in South Bohemia in the Czech Republic. There are likely many reasons, such as climate, building insulation and thermal systems, but also due to human factors such as thermal comfort. Guidelines about optimal and comfortable room temperature have changed over time in Europe. For example in France, an early 20th century guide described a room temperature of 14°C in the living room being recommended, and a temperature of 11°C in the bedroom, while as soon as in a 1958 guidebook a room temperature of 18°C was suggested being optimal. (Sahakian and Naef 2019, 10.) Current guidelines in European countries demonstrate that there is significant variation between the countries in recommended indoor temperatures: the requirements range from 25 to 28°C in the summer and 15 to 20°C in the winter (Brelih 2013, 16). Indoor temperatures for energy standards show similar variation ranging from 21-22°C in Finland and Sweden to 20°C in the southern European countries of Spain, Italy and Portugal to as low as 18-19°C in western European countries such as the UK and Germany (Laakso & Heiskanen 2017, 15). Sahakian and Naef (2019, 11) state in their report that thermal comfort is a complex issue affected by many other aspects than just cultural context. For instance, individuals have reported feeling comfortable in highly varying degrees (Sahakian and Naef 2019).

According to previous research (Schmitz and Stamminger 2014; Alborzi et al. 2017), contemporary laundry washing practices vary within Europe to some degree The number of washing cycles is the most important factor when considering energy and water usage of laundry washing (Schmitz and Stamminger 2014, 942). The authors studied European households' laundry washing practices, and noted that the average number of washing cycles of the households was 3.8 cycles per week, ranging from 3.5 (France, Sweden & Czech Republic) to 4.1 (Italy) in the participating countries. The number of washing cycles per person per week ranged from 1.2 in Hungary, Spain and Czech Republic to 1.5 in Finland, UK, Sweden, and Denmark (Schmitz and Stamminger 2014, 942-943). The second important factor in terms of resource use of laundry washing is the water temperature. In Schmitz and Stamminger's (2014, 942) study, the most used temperature in European households was 40°C (40% of all programmes used), while the second most used programme was 60°C (19%). There are, however, considerable variations between countries. In Finland, for example, over 50% of washing cycles were washed in 40°C programmes and only 10% in cold temperatures of 30°C or less. In contrary, in the UK and France nearly 35% of washing cycles were run in 30°C programmes. The average washing temperatures ranged from 30.9 °C (Spain) to 47.4°C (Poland). (Schmitz and Stamminger 2014, 942-943.)

As discussed in previous chapters, the socially shared conventions, i.e. the collectively shared practices and expectations about energy consumption (Laakso & Heiskanen 2017, 15) and the historical and culturally bounded trajectories of practices (Warde 2005) are likely contributing to the differences observed in energy consumption practices within Europe. Vávra et al. (2015, 152-153) for instance suggest based on their research that the low room temperatures in the UK seem to be an established practice that remains irrespective of energy price level. In Germany, where households use energy economically and the room temperatures are moderate, things such as education campaigns in the 80s have advanced the establishment of economic energy consumption practices.

The number of studies comparing intervention outcomes in different geographical or cultural contexts have been rare, as I discussed in the introduction, but there are a few studies and meta-analyses, which have addressed the issue to some extent. Morren and Grinstein (2016) conducted a meta-analysis, in which they focused on the role of different national contexts in explaining the intention to and actual pro-environmental behaviour. They found a positive relationship between the wealth of the country and pro-environmental behaviour, suggesting that economic capabilities and technological advancements create better opportunities to behave environmentally consciously (pp. 102). Another finding from the study was that in individualistic cultures, intentions to behave pro-environmentally predicted the actual behaviour better than in collectivist cultures. Morren and Grinstein (2016, 102) suggest that this could be explained by the related cost reductions and the possibility to enhance social status. Different physical environment and national energy systems may also influence intervention outcomes.

To sum up, household energy consumption practices and intervention outcomes vary among different national and cultural context. Differences in conventional heating and laundering practices can be seen as being formed by both the historical and cultural trajectories of practices, conventions and the past and present political and cultural guidelines. Economic and cultural differences between countries are potentially influencing intervention outcomes, as are the physical environment and national energy systems. Despite the low number of previous cross-national comparative studies of intervention outcomes, there is research suggesting that the role of geographical and cultural context is of importance. I will next turn to the material and institutional context, which, as will be evident, is closely connected to the national and cultural context in household energy consumption.

2.3.2 Material and institutional context

Laakso and Heiskanen (2017, 10-15) highlight the role of material and institutional conditions in relation to the abilities of people to make changes in their energy consumption behaviour. The opportunities for people to save energy in space heating may be significantly different in old and new buildings, or big and small apartments (pp. 10-11). Building type may also be a significant factor in changing household energy consumption; people living in detached houses usually have more control in terms of their energy consumption compared to people living in semi-detached houses or apartment buildings, for instance in their choice of heating system. Laakso and Heiskanen (2017, 11) also note that there are differences between the European countries in the share of the different building types. Physical traits of the buildings, such as the heat leakage from an apartment to another in apartment block buildings could also restrict households to adjust their apartment's temperature (Laakso & Heiskanen 2017, 12).

Tenure type constitutes a contextual factor, which potentially has significant impact on energy consumption and the ability to change it. Making renovations to improve energy efficiency may not be possible in rental apartments, and at the same time, property owners may be unwilling to invest in such improvements. (Laakso & Heiskanen 2017, 13.) Tenancy was connected to poorer intervention outcomes in several studies Šćepanović et al. (2017, 1162) analysed in their meta-analysis. As discussed in the previous chapter, variations in room temperatures between countries have been observed in both guidelines and measured room temperatures, but the variations are also likely to be affected by institutional and material factors. Vávra et al. (2015) compared living room temperatures in different countries and found that in Germany and the Czech Republic the living room temperatures were higher when there were more insulation measures in the house (pp. 151). Insulation can, thus, on the one hand be relevant in saving energy in heating, but on the other, offer enable having higher room temperatures.

Insulation and other technical enhancements as well as the efficiency in energy practices thus affect the level of consumption. Šćepanović et al. (2017, 1157) noticed in their meta-analysis that households, which are already efficient, are limited in their ability to lower consumption. Similarly, Abrahamse et al. (2005, 281) discovered that in some of the studies they reviewed feedback on energy consumption was dependent on the energy consumption levels: high consuming people reduced their consumption while low consuming people increased it. The level of energy consumption may thus dependent on material factors, but also as such affect the intervention outcomes. National energy systems are institutional factors, but also closely connected to their geographical context. A study by Winther and Bell (2017) comparing domestic energy consumption reductions in Norway and the UK found that because the energy in the UK was more fossil intensive, the residents in UK were more concerned with environmental issues. The study also found that in Norway, where electricity prices were volatile, getting feedback from consumption motivated to reduce it (pp. 34).

Material and institutional context appears to be especially important with regard to room temperature, because the significant factors found in the literature are mainly related to buildings, such as type of the building, insulation or the ability to make renovations. Institutional factors such as energy systems are relevant to energy consumption more generally, and may thus be potentially significant with regard to a wider spectrum of household energy practices. Many of the material and institutional factors discussed in this chapter, such as building type or energy systems, are also closely connected to the geographical and cultural context, as the report of Laakso and Heiskanen (2017) and the study of Winther and Bell (2017) demonstrate.

2.3.3 Socio-economic and demographic context

Socio-economic context is often discussed in research on household energy consumption. Several studies shoe a positive relationship between larger incomes and energy consumption in households (e.g. Abrahamse & Steg 2009, 719; Vávra et al. 2015, 154). Vávra et al. (2015) for example found a positive connection with household income and room temperatures. Although higher income is often connected to an increased use of energy, these households also hold a greater potential for reducing their energy consumption by being able to acquire more costly equipment, such as better insulation or to make technical changes in heating systems (Abrahamse and Steg 2009, 719). Šćepanović et al. (2017) conducted a meta-analysis of residential energy interventions and evaluated their effectiveness from the perspective of different contexts. They concluded that low income households or ‘vulnerable households’ was the socio-economic factor that was most often found to be connected to intervention outcomes (pp. 1162). These households were generally less motivated or engaged in interventions, but Šćepanović et al. (2017) added that, in general, socio-economic factors may play a role in intervention outcomes and they should not be disregarded, but that certain intervention strategies, such as social norms, goal setting or commitment may be more resilient to socio-economic factors than others (pp. 1162).

According to their study of French households' energy use and conservation behaviour, Belaïd and Garcia (2016) found that education level had a negative impact on energy saving behaviour, but a study conducted by Pothitou et al. (2017) found no connection between education level and pro-environmental behaviour. According to another study (Vávra et al. 2015), education and employment status were not significant predictors of living room temperatures. Alborzi et al. (2017), in contrast, found that people with elementary education washed fewer cycles than did people with higher educational level.

According Belaïd and Garcia (2016) both young and old were engaging more in energy-saving behaviour, while adults 28-45 of age engaged less in energy-saving behaviour. The authors assume this to be due to having young children in the family and favouring the comfort of the children over savings in energy. Vávra et al. (2015) found in their study that in Germany people aged over 60 years had higher room temperatures than younger people did. Šćepanović et al. (2017, 1162) found, on the other hand, that there was a negative connection between the age of the youngest household member and energy consumption, suggesting that families with small children are using more energy. Alborzi et al. (2017) found that older people washed fewer laundry cycles.

Some studies have noted that socioeconomic and demographic factors were connected to energy consumption in a different manner than to intervention outcomes. Abrahamse and Steg (2009) studied the relationship of socio-demographic and psychological factors to household energy consumption and energy savings in an intervention study in the Netherlands. The results suggest that, although socio-demographic factors such as income and household size were positively connected to the energy consumption, socio-demographic factors were not related to energy saving behaviour. The intervention did generate savings, but these savings were, thus, similar in different socio-economic groups. (pp. 719.) Brandon and Lewis (1999) made similar findings stating that, although income, age and the number of people in the households were significant predictors of previous energy consumption, they were not connected to the intervention outcomes (pp. 81-83).

The social relations influence behaviour in many ways; family members' (lack of) communication, for instance, may influence the intervention outcomes. If not all members are committed, but still affected by the intervention, this may result in poor outcomes. (Heiskanen at al. 2019a.) Strengers et al. (2016) have demonstrated how the traditional definition of a consumer can be misleading in the context of household energy consumption. Babies, teenagers, houseguests and pets, while not seen as energy consumers, may significantly affect household energy use practices. Teenagers, for instance, can be high energy consumers due to their ICT practices, but at the same time are not in charge of energy bills or in choosing the energy company (Strengers et al. 2016, 768). Pets can similarly influence the ways in which energy is consumed: many cats love warm places, which could result in heaters being on longer than otherwise, and for example a door might be kept open to enable the dog go outside resulting in wasted energy (Strengers et al. 2016, 773). Alborzi et al. (2017, 680) suggest base on their study, that people who mentioned work involvement or contact with animals at work as the reason to wash clothes washed more cycles than other. The authors found also a significant positive connection between families with babies or small children, or other people needing extra care, and weekly laundry cycles. (pp. 680.)

A multitude of socioeconomic and demographic factors has been linked to household energy consumption in previous studies. The results on the role of some factors, such as income, are more in line with each other, while the role of some others are more ambiguous. Additionally, some studies found that although some socioeconomic and demographic factors predicted energy consumption prior to intervention, they were not similarly connected to the intervention outcomes.

2.4 Research questions

The literature review demonstrated that household energy consumption and energy interventions have been studied extensively during the past decades. The focus has ranged from individuals to practices, and to energy cultures, depending on the research tradition. According to previous research, energy consumption in households is affected by a multitude of contextual factors, and although research on the role of contextual factors in energy interventions has been given less attention, the evidence suggest that the outcomes may be significantly affected by the context in which the interventions are carried out.

The aim of my thesis is to analyse the significance of contextual factors in relation to household energy intervention outcomes. Previously, the outcomes of energy interventions have typically been evaluated in terms of the different intervention strategies used, but in the present paper, the context in which the interventions are carried out is at the centre of the analysis. This thesis seeks to provide further insight into the significance of the external context in behaviour interventions to advance future intervention design and to improve their scalability. In addition, this thesis aims at providing new knowledge about cross-national comparisons in intervention studies, which is an area so far given little attention to. In order to respond to these objectives, I will use data collected in the ENERGISE intervention and analyse it using quantitative research methods. I have summarized the aims of this paper into the following research questions:

1. Are there any differences in the outcomes of the ENERGISE intervention in different national contexts?

2. Are there any differences in the intervention outcomes according to other contextual factors, such as material, socioeconomic or demographic context?

3. Research data and methodology

In this chapter, I describe the research data and the methodology I have used in my thesis. I begin the chapter by introducing the ENERGISE research initiative in more detail, focusing on the design of the living laboratories as well as the intervention and research processes. Next, I describe the data collection process and the combining of data from the eight participating countries. I also describe variables I used. Lastly, in this chapter, I describe the methodological choices made and the process of analysis.

3.1 The ENERGISE research initiative

ENERGISE was a three-year (2016-2019) “innovative pan-European research initiative to achieve a greater scientific understanding of the social and cultural influences on energy consumption” (Rau & Grealis 2017, 4), funded by EU Horizon 2020 programme. Eight European countries participated in the study: Switzerland, Germany, Denmark, Finland, Hungary, Ireland, the Netherlands and the UK. ENERGISE utilized the concept of ‘Living Laboratories’ as the approach to study energy practices, which, according to Almirall et al (2012, 12), is “driven by two main ideas: i) involving users as co-creators on equal grounds with the rest of the participants and ii) experimenting in real-life setting”. Living labs have been used by various organizations such as universities, government organizations and private companies due to the ability to produce more useful knowledge and to achieve faster social and technical changes (Schliwa et al. 2015). In the planning process of ENERGISE Living Labs (ELLs) special attention was given to the context dependency of intervention effectiveness by producing a database of sustainable energy consumption initiatives in Europe and by identifying interventions working across national context (Jensen et al. 2017). The context dependency was also addressed by identifying differences in e.g. billing practices, housing stock and socio-economic conditions in Europe (Laakso et al. 2017).

In ENERGISE a total of 16 living labs were implemented: in each country one living lab for individual households and one living lab within a community context, involving in total 306 households. The process of recruiting households was determined individually in each country. In most of the countries, the suitable locations for both ELLs were first identified, and the recruitment of households occurred with the help of local partners who were acquainted with the community or region. Common tools used to contact the households included social media, newspaper advertisements, direct surveys and local community events. (Vadovics and Goggins 2019.) In each living labs, two interventions were carried out to reduce the amount of energy consumption in 1) space heating, and 2) laundry washing. Space heating was chosen due to it being the most energy intensive household practice and therefore an important domain for energy reductions. Laundry washing, although accounting for a relatively small amount of households’ overall energy consumption, is significant to overall sustainability of households due to its many connections with other household practices, such as shopping clothes and laundry-related products, as well as drying and ironing (Laakso et al. 2019.) The intervention method used in ENERGISE was *challenge*. With regard to space heating, the households were challenged to reduce their indoor daytime temperature to 18°C, and with regard to laundry washing, the households were challenged to reduce their laundry washing by half. The households were also able to define their own targets if they found it more suitable for their situation. (Vadovics and Goggins 2019.)

The outline of the ELL process is presented in Figure 1. The process can be divided into three main periods: baseline period, challenge periods, and follow-up period (which is not covered in this thesis). All households were visited individually before the beginning of the baseline period. Interviews were conducted with households in the individual living labs both before and after the challenges, while community living labs had collective elements, such as focus group discussions before and after the challenges. In addition, in order to provide peer support, the collective living labs were given the opportunity to share thoughts, ideas and experiences through social media groups. (Vadovics and Goggins 2019.) The quantitative data collection process in each phase of the living labs is explained in detail in the next chapter.

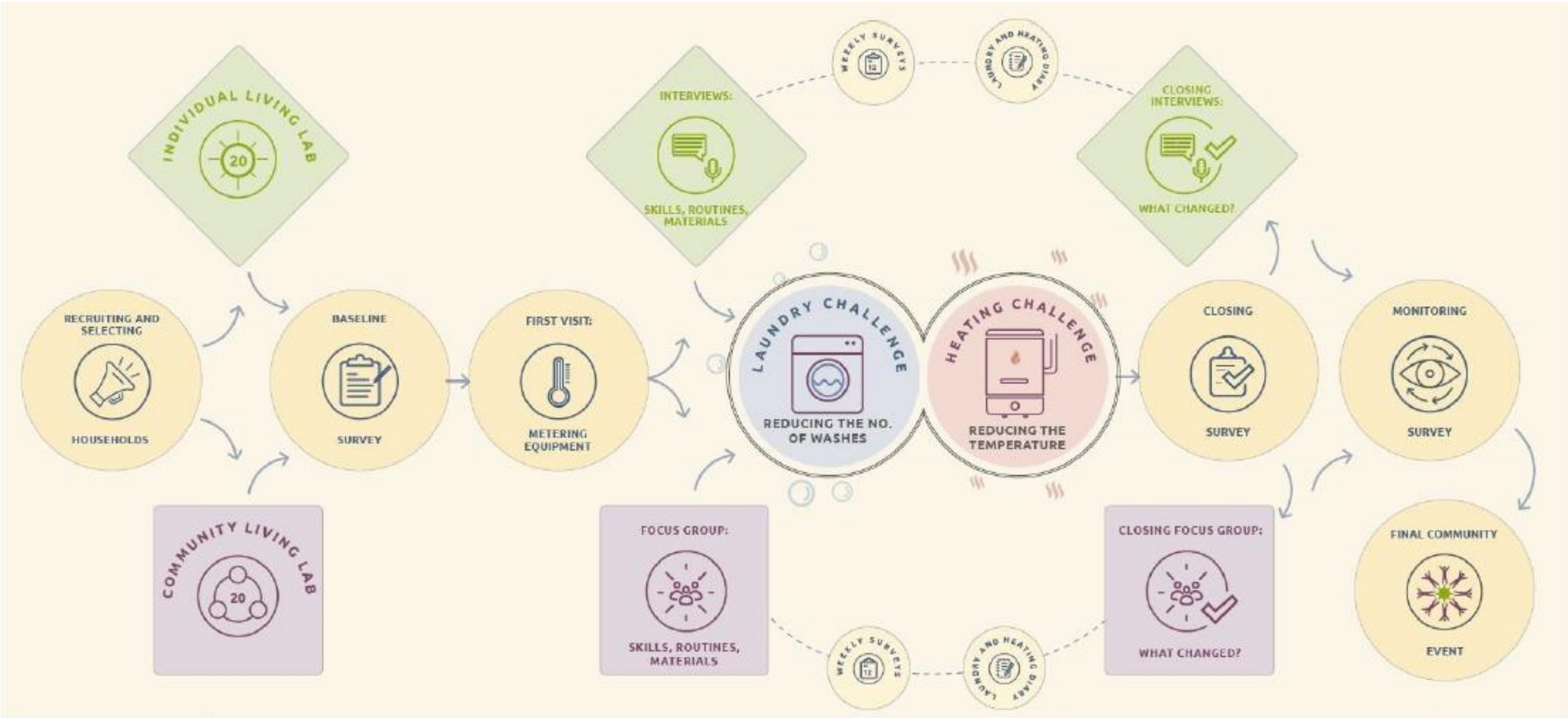

Figure 1 The ENERGISE Living Lab process

3.2 Data collection and combining

The process of data collection can be divided in two parts: the first part covers data collection made by the research teams in each participating country, and the second part covers the combining of the country specific data files into a single data matrix made by myself. After explaining the data collection process in detail, I describe the variables I have decided to use in the analysis and the modifications that were needed, and lastly, explain the analysis process in detail, including the methodological decisions I have made.

Initial data collection process took place in each individual country and it occurred between June 2018 and November 2018, before my participation in the project. Initially, 13-22 households were recruited in each of the 16 living laboratories, and the total number of participating households was 306. 162 households were recruited in the individual living labs and 144 in the community living labs. At first, **a recruitment survey** was conducted to collect basic information about the households, such as the type of dwelling and heating, apartment size, ages and education levels of family members, and the ability of the households to adjust room temperature. A baseline period between four (in laundry) to seven (in heating) weeks prior to the four-week challenge period started in September 2018 in most of the countries. Prior to the challenge period, **a baseline survey** was conducted to collect information about households' laundry and heating practices and their perceptions about comfortable room temperatures. During the baseline and challenge periods, households were requested to keep **diaries** of their laundry cycles and room temperatures. Additionally, **weekly surveys** were conducted during the baseline and challenge periods to collect data on room temperatures, number of weekly laundry cycles and the participants' emotions during the challenge weeks. After the challenge period, in a **closing survey** the participants were, among other things, requested to evaluate their practices both during and after the challenge.

The data collection was conducted individually in each country and the data obtained was reported to a common data platform. Each country's research team provided one data file for each survey and each living laboratory (individual and community), except for Hungary, whose data files included both individual and community data. Each country collected weekly surveys during a period of 11 weeks (except for Hungary and Ireland, who had collected 10 weekly surveys), which totals in 86 sheets of data for each living laboratory, and 172 sheets of weekly surveys in the data. Table 1 presents information on data collection time line, surveys, number of respondents, and the number of original data files for each survey.

Table 1 Surveys collected, the number of respondents, the number of original data files, and the period of data collection.

	N	Number of data files	Collection period
Recruitment survey	306	15	June - October 2018
Baseline survey[a]	292	15	August – November 2018
Closing survey[a]	264	15	November 2018 – February 2019
Laundry diaries [b]	273	15	September – November 2018
Weekly surveys	285	172	September – November 2018

[a] Data collected in these surveys was not used in the analysis conducted in this thesis, but they have been used in other studies (Matschoss et al. forthcoming; Sahakian et al. 2019).

[b] Laundry data from Hungary (n = 41) is primarily based on weekly surveys, supplemented with data from the laundry diaries.

I started combining the data files in January 2019. I first created a combined data matrix for each survey. Recruitment survey data was the most challenging, because it was collected with several different survey applications (the common tool used in later surveys was not available at that time), and the output files were in several different formats that were not straightforwardly combinable with each other. The format of four countries' data files were similar and I was able to combine them directly in SPSS, but the other four countries' files required substantial and time-consuming modifications to make them compatible with the other data. Therefore, I needed to specify the variables I wanted to use from the recruitment surveys already at this point.

Baseline and closing surveys, as well as weekly surveys were collected with a common survey tool and therefore the data outputs from all countries were in similar format. The combining of the data was less complicated than that of the recruitment surveys, although some preparation in Excel was necessary to enable smooth combining in SPSS, such as renaming some of the variables and replacing empty cell with a zero were necessary. Weekly surveys included in total 172 Excel sheets, and since it is possible to import only one sheet at the time in SPSS, I decided to consolidate each file's data into a new sheet in Excel, and this way managed to reduce the number of files to be merged in SPSS into 15. Laundry diary data were originally collected in paper format, and manually entered into Excel afterwards. The resulting 15 Excel files were rather similar to each other and only small modifications in Excel were required before importing them into SPSS. Last step in the process was to combine each survey's data in SPSS into one data matrix, which then contained in total 801 variables.

3.3 Variables

3.3.1 Dependent variables

To measure intervention outcomes in space heating, I decided to calculate the difference of average room temperatures between baseline period and challenge period. The data used in these variables is from the weekly surveys, which the participants filled in each week. Baseline period length for space heating was seven weeks, except for two countries, Hungary and Ireland, where the baseline period was six weeks long. The challenge period length was four weeks in all eight countries. Based on the weekly survey data, I calculated the average temperatures in each household for both periods, baseline and challenge. I then calculated the dependent variable by subtracting the average challenge temperature from the average baseline temperature. The temperatures were calculated for all cases that had at least one response in both periods. In the weekly surveys, the temperature data was requested for three rooms: living room, bedroom and a second bedroom. I decided to calculate the temperature reduction variable for two rooms, living room and bedroom, and exclude the second bedroom due to a low number of responses.

To measure the intervention outcomes of laundry challenge, I decided to compare the weekly average laundry cycles between the baseline and challenge periods. The data for this variable is based on laundry diaries (except for Hungary, where the main data source is weekly surveys supplemented with information from laundry diaries), which the participants kept during the baseline and challenge periods. I calculated the variable as a proportional reduction, because the challenge stated in the intervention was to reduce laundry by half compared to the baseline period. This calculation also made the data in different sized households more comparable. Baseline period for laundry cycles was four weeks, except for Hungary and Ireland, where the baseline period was three weeks long. However, the length the participants actually kept the diary varied to some degree and the number of baseline weekly average cycles is calculated based on that. Challenge period length was four weeks in all countries. I first calculated the average weekly laundry cycles for the baseline and the challenge periods, and thereafter the reduction in the average weekly laundry cycles as a percentage compared to the baseline.

3.3.2 Independent variables

The selection of the independent variables was primarily based on the previous literature, but it was naturally restricted by availability of data. To analyse the role of geographical and cultural context, I compared the intervention outcomes in the eight participating **countries** (Switzerland, Denmark, Germany, Finland, Hungary, Ireland, The Netherlands, and the UK). I added the country variable for each data file already when I received them in Excel form, and the variable did not require any additional modifications in SPSS. **Building type** originally included seven categories, “detached houses”, “semi-detached houses”, “terraced houses”, “apartment buildings”, “student housing”, “senior housing”, and “other”. I modified the building type variable to include three categories: detached houses, semi-detached or terraced houses (including the original categories of semi-detached houses and terraced houses), and apartment buildings or others (including the remaining categories). **Living room baseline temperature** and **bedroom baseline temperature** variables measure the average living room and bedroom temperatures during the baseline period. The **baseline laundry cycles** variable measures the number of average weekly laundry cycles during the baseline period[1].

I included a number of variables describing the socioeconomic and demographic attributes of the households to see if they could explain differences in intervention outcomes. Household income level data was not available, and therefore, to analyse the effect of the socioeconomic status of the households I used **contact person education[2]** and **contact person occupational status** variables. Because 72% of the contact persons had higher education, I decided to compare just two groups, “higher education” and “lower education”. Similarly, I decided to compare two groups according to occupational status: I combined full-time employees and entrepreneurs into one group (“full-time employment”) and all other occupational statuses into another group (“other”). **Contact person age** was originally (in all countries except in Ireland) a continuous variable, but I changed it into a categorical variable. The categories are 25-34, 35-44, 45-54, and 65 or older, and they were based on the categorisation in the Irish data. I also analysed the intervention outcomes in different sized families. **Family size** variable has in total five categories, 1, 2, 3, 4, and 5 or more persons.

3.4 Methodology

I performed the data management and analysis using SPSS version 25.0. The analyses were carried out in two phases. In the first phase, I looked at the main effects of the independent variables. The purpose of the first phase of the analysis was to study the individual relationships between dependent and independent variables and to identify significant predictors for the second phase of the analysis. In the second phase, I formed multivariate linear regression models based on the analysis conducted in the first phase.

[1] See the descriptions of dependent variables for a more detailed information on how the baseline variables were calculated.

[2] For Ireland, the data represents household highest education level, not contact person highest education.

The purpose of the second phase was to investigate how the role of each factor might change compared to the analysis of the main effects, when controlling for a number of other variables. The methodologies used in this thesis include one-way analysis of variance (ANOVA), independent samples t-test, Pearson correlation, and multiple linear regression, which are all methods that are suitable for analysing interval dependent variables, as is the case in this thesis.

In the first phase of the analysis, I used the following methods: a one-way ANOVA, an independent samples t-test and Pearson's correlation. A one-way ANOVA is a suitable method for situations where the independent variable is categorical, and three or more unrelated groups are compared (Nummenmaa, 2004, 173, 179). I used the one-way ANOVA to compare the intervention outcomes in terms of the following variables: country, building type, family size, and contact person age. In the one-way ANOVA models, some of the group sizes in the country comparisons were rather small (under 30), and therefore I tested the normality of their distribution with Shapiro Wilks test. The test results showed that the distributions of the dependent variables were not normal in all of the compared groups, which might be affecting the reliability of the analyses. However, the one-way ANOVA is a rather robust model to small violations against its assumptions (Nummenmaa 2004, 182) and because the analyses fulfilled other central assumptions (group sizes were over 20 and rather similar, and Levene's tests showed homogeneity of group variances), I decided to use the one-way ANOVA model also for the country comparisons. In case statistically significant differences between the group means were found, I conducted post-hoc comparisons using Tukey HSD test to determine which groups differed from each other. An independent samples t-test is a suitable method for situations where two independent groups are compared (Nummenmaa, 2004, 160). I used an independent samples t-test to compare the intervention outcomes in terms of contact person education and contact person employment status. To study the relationship of two interval variables, I used Pearson's product moment correlation coefficient. I calculated the correlation coefficients for the baseline temperatures in living rooms and bedrooms, the baseline weekly average laundry cycles, and the dependent variables.

In the second phase, I used multiple regression analysis to form multivariate models for each dependent variable. Linear regression is a suitable method for explaining the relationship between a continuous dependent variable, and multiple independent variables, which can be either continuous or categorical (Nummenmaa 2004). I formed three multiple regression models, one for each dependent variable. The models were predetermined based on the analysis of main effects in the first phase. For the regression analysis, I created dummy variables for country, building type, family size and contact person age variables. Although family size and contact person age were interval variables, the relationship with the dependent variables appeared not to be linear, which is an important assumption of linear regression, and therefore I treated them as categorical variables. I tested the regression models for multicollinearity using the variance inflation factor (VIF). The lowest possible value for VIF is 1.0, which indicates that there is no multicollinearity between the independent variables (Vogt 2007, 175). In his book Vogt (2007, 175) suggests that a VIF value of 5.0 is a good rule-of-thumb figure indicating a possible problem with multicollinearity. The VIF values in the three models varied between 1.3 and 2.3, and most values were below 2.0 suggesting that the independent variables did not correlate with each other to an extent that would have been problematic.

4. Results

In this chapter, I introduce the results from the analysis. I first provide some general descriptions of the data and the participating households. After that, I first introduce the results from the first phase of the analysis, where I studied the main effects of the independent variables in relation to the three dependent variables. The last part of the chapter introduces the results from the multiple regression analyses.

4.1 Descriptive statistics

Some basic characteristics of the households by country are summarized in Table 2. Family size of participating households varied from single-person households to eight-person households. 30% of the households were two-person households, which was the most typical household size in the data. The second largest household size was four person households accounting for 27% of the participating households. 13% of the households were single-person households, which was the smallest category. There was some variation in the data between the countries: In Hungary, Ireland and the UK the participating households were rather equally represented in the three categories. In Germany, Switzerland and Denmark only a few families with five or more persons participated the initiative. In the Netherlands, the majority of the households were small households with only 1 to 2 persons.

42% of the participants lived in detached houses, 31% in semi-detached or terraced houses, and 25% in apartment buildings, but there was variation to this between the countries. In Switzerland, for example, 32 of 35 households lived in an apartment building, while in Germany, Denmark and Hungary a vast majority of households lived in a detached, semi-detached or terraced house, and only a minority in apartment buildings. Finland, in contrary, had about half of the participants living in detached houses and the other half in apartment buildings.

Table 2 Household basic characteristics by country

		Switzerland	Germany	Denmark	Finland	Hungary	Ireland	Netherlands	UK	Total (n)	Total (%)
Family size	1 person	5	3	4	10	4	0	7	6	39	13 %
	2 persons	6	12	13	17	8	14	12	7	89	30 %
	3 persons	7	8	5	8	5	3	2	2	40	14 %
	4 persons	14	15	14	4	12	9	6	6	80	27 %
	5 or more pers.	3	1	2	4	12	10	5	11	48	16 %
	N	*35*	*39*	*38*	*43*	*41*	*36*	*32*	*32*	*296*	*100 %*
Contact person age	25-34	4	4	3	9	4	2	2	3	31	10 %
	35-44	8	17	7	8	11	10	8	5	74	25 %
	45-54	15	8	13	10	15	12	6	15	94	32 %
	55-64	3	5	9	9	8	9	6	7	56	19 %
	65-	4	5	6	7	3	3	10	1	39	13 %
	N	*35*	*39*	*38*	*43*	*41*	*36*	*32*	*32*	*296*	*100 %*
Building type	Detached	2	14	19	20	30	32	4	4	125	42 %
	Semi-detached or terraced	0	19	19	1	10	4	17	23	93	31 %
	Apartment building	32	7	0	22	1	0	7	5	74	25 %
	Other	1	0	0	0	0	0	4	1	6	2 %
	N	*35*	*40*	*38*	*43*	*41*	*36*	*32*	*33*	*298*	*100 %*
Ownership	Tenant	20	11	2	10	0	1	0	7	51	19 %
	Owner	6	29	35	33	41	34	2	26	206	77 %
	Other	10	0	1	0	0	1	0	0	12	4 %
	N	*36*	*40*	*38*	*43*	*41*	*36*	*2*	*33*	*269*	*100 %*
Contact person gender	Female	18	24	22	25	27	23	20	18	177	60 %
	Male	18	16	16	16	14	13	12	15	120	40 %
	N	*36*	*40*	*38*	*41*	*41*	*36*	*32*	*33*	*297*	*100 %*
Contact person education	Higher education	30	26	20	25	34	31	21	20	207	72 %
	Secondary education	1	10	13	4	6	1	2	5	42	15 %
	Vocational education/training	3	0	4	10	1	1	2	3	24	8 %
	Basic	1	3	1	0	0	0	0	3	15	5 %
	Other	1	1	0	1	0	3	0	1	7	2 %
	N	*36*	*40*	*38*	*40*	*41*	*36*	*25*	*32*	*288*	*100 %*
Contact person employment status	Full-time employment	10	18	21	22	22	20	4	7	124	46 %
	Part-time employment	17	12	2	1	2	7	3	8	52	19 %
	Entrepreneur	3	3	5	7	6	2	1	10	37	14 %
	Unemployed	0	1	1	0	0	0	0	2	4	1 %
	Student	1	0	0	3	0	0	0	1	5	2 %
	Retired	3	5	7	4	5	4	0	2	30	11 %
	Other	1	0	2	1	6	3	0	3	16	6 %
	N	*35*	*39*	*38*	*38*	*41*	*36*	*8*	*33*	*268*	*100 %*

A majority of the household contact persons were 35-44 (25%) or 45-54 (32%), but overall the contact person age varied from 25 to 79. The contact person age varied between the countries to some extent, but the differences were not especially distinctive. In the Netherlands, there were more households with contact persons aged over 65 than in the other countries, which may also be connected to the family size of the participants. 60% of the contact persons were females and 40% males, and in most countries, the share of female and male contact persons was similar.

77% of all respondents were homeowners and 19% tenants. In Hungary, all respondents were owners, but in other countries, there were both owners and tenants participating in the intervention. In terms of education, 72% of household contact persons had a higher education, 15% secondary education, 8% vocational and 5% had basic or other form of education. This means that higher education group is somewhat overrepresented in the study. Almost half (46%) of the household contact persons were full-time employed, one fifth (19%) part-time employed, 14% entrepreneurs, 11% retired, and the remaining 9% were students, unemployed or other.

The total number of valid cases in the temperature reduction variables were 265 in living room temperature reduction and 264 in bedroom temperature reduction. The number of missing cases were 41 and 42 respectively. The mean temperature reduction in living room was 0.95°C, and 1.38°C in bedroom. The values varied from an increase of 3.57 degrees to a decrease of 4.63 degrees in living room, and from an increase of 2.83 degrees to a decrease of 5.11 degrees in bedroom. The number of valid cases in the average weekly laundry cycle reduction variable was 251, and the number of missing cases was 55. The average reduction in weekly laundry cycles was 25.1%, and the values varied from an increase of 250% to a reduction of 100%. The total number of valid and missing cases, mean, median, standard deviation, and minimum and maximum values of the dependent variables are presented in Table 3.

Table 3 basic statistics of dependent variables

		Temperature reduction living room	Temperature reduction bedroom	Laundry cycle reduction
	Valid	265	264	251
N	Missing	41	42	55
	Total	306	306	306
Mean		0.95	1.38	25.1
Median		0.98	1.35	30.7
Std. Deviation		1.22	1.25	38.2
Minimum		-3.57	-2.83	-250.0
Maximum		4.63	5.11	100.0

4.2 Country

In all eight countries, households reduced the average living room and bedroom temperatures during the challenge period. There was some variation between the countries in the average baseline temperatures in both living room and bedroom. The average baseline temperatures were highest in Switzerland in both rooms: 22.3°C in living room and 21.8°C in bedroom. The lowest baseline temperatures were measured in Ireland: 19.7°C in living room and 17.5°C in bedroom. The country average temperatures during baseline and challenge periods in living rooms and bedrooms are presented in Figure 2.

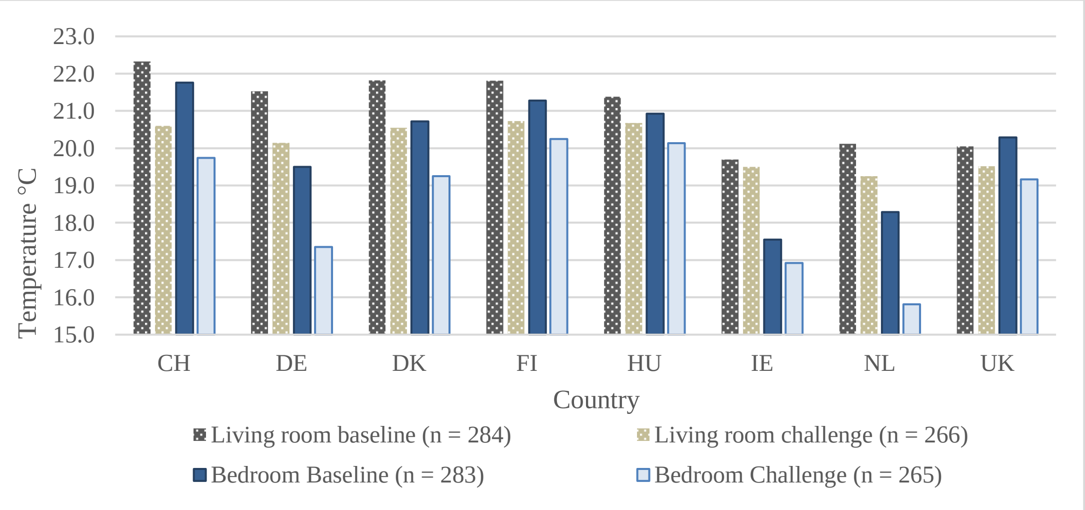

Figure 2 Average temperatures in living room during baseline and challenge period by country

The average reductions in living room temperatures varied from 1.85°C in Switzerland to 0.21°C in Ireland, and in bedrooms from 2.35°C in the Netherlands to 0.62°C in Ireland. In seven out of eight countries, (Finland being the exception) households reduced the bedroom temperatures more than the living room temperatures, although the baseline temperatures were higher in living rooms in all countries except in the UK. Temperature reductions by country are presented in Figure 3.

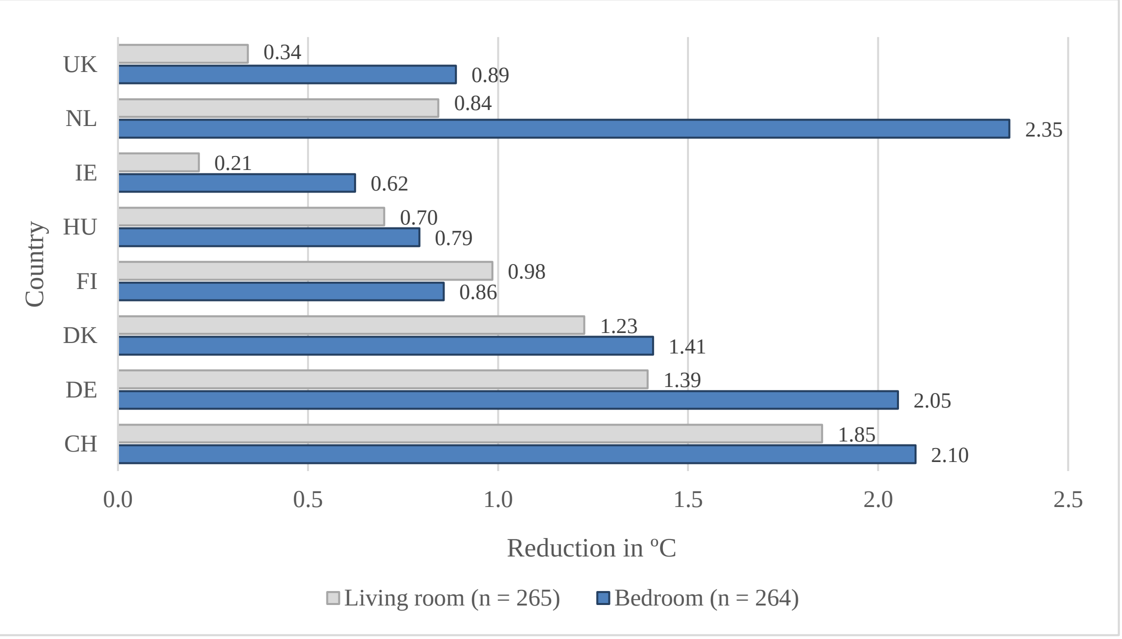

Figure 3 Reductions in living room and bedroom temperatures in the baseline and the challenge periods by country

The average number of weekly laundry cycles in the whole data in the baseline period was 4.2 and in the challenge period 3.0. The number of average weekly laundry cycles in the baseline period varied from 6.6 in Ireland to 2.7 in Switzerland. The average weekly laundry cycles in the challenge period varied from 5.2 in Ireland to 1.6 in Switzerland. The average weekly laundry cycles by country in baseline and challenge periods are presented in Figure 4.

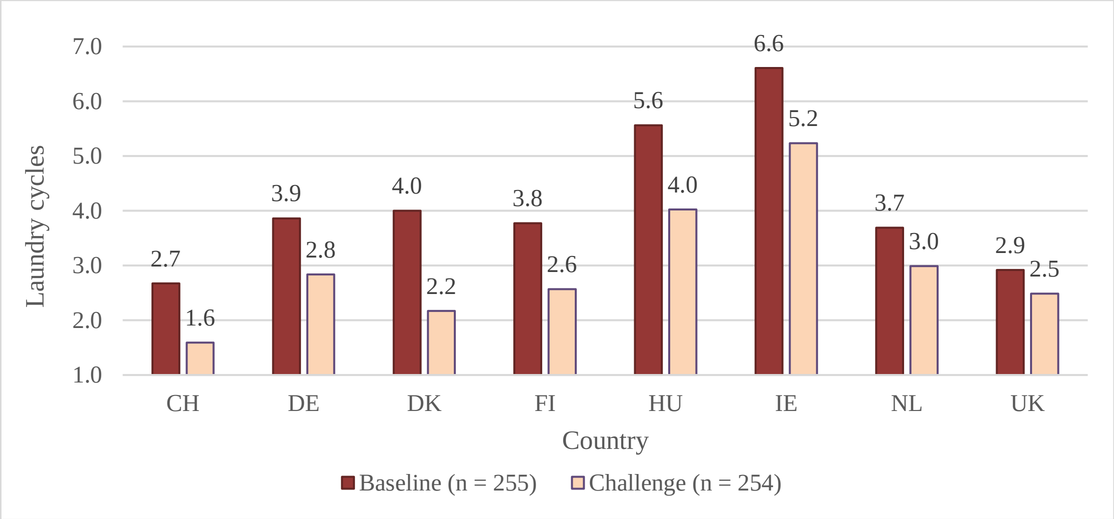

Figure 4 Weekly average laundry cycles in baseline and challenge period by country

The number of weekly laundry cycles was reduced by 25.1% on average in the challenge period compared to baseline period. The highest average reduction was made in Denmark (46.1%), and the lowest average reduction in Ireland (12.8%). The average reductions of weekly laundry cycles in each country are presented in Figure 5.

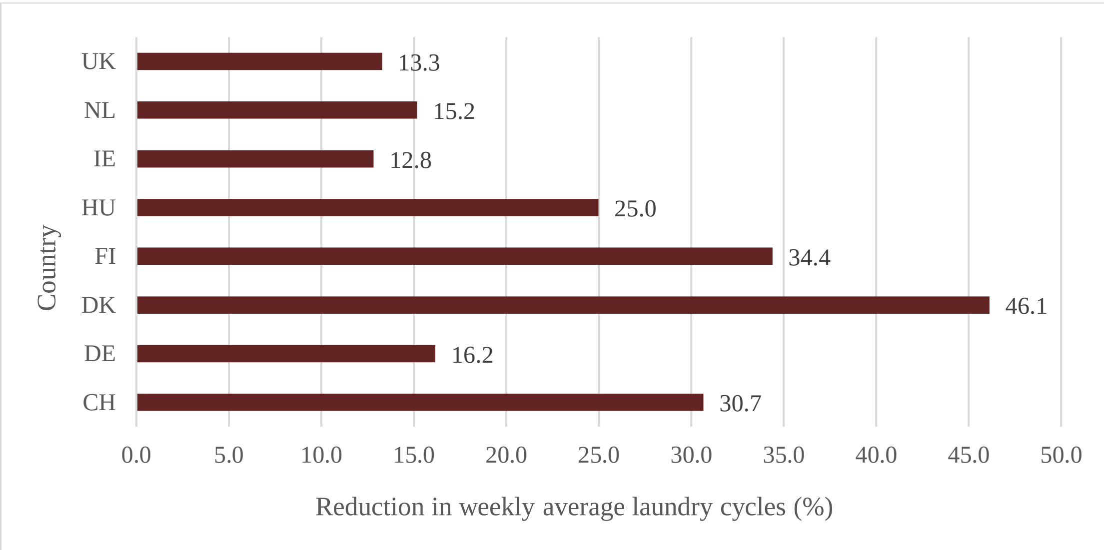

Figure 5 Weekly average laundry cycle reductions by country

I conducted one-way ANOVA analyses to compare the intervention outcomes of heating and laundry challenges in the eight countries. The ANOVA results show that there were statistically significant differences between the group means of the countries in living room temperature reduction [$F(7, 257) = 7.288$, $p < 0.000$], in bedroom temperature reduction [$F(7, 256) = 13.394$, $p < 0.000$] and in the average reduction of weekly laundry cycles [$F(7, 243) = 3.264$, $p < 0.002$]. The mean reductions of living room and bedroom temperatures and laundry cycles, and standard deviations by country are presented in Table 4.

Table 4 Temperature reductions in living room and bedroom

		N	Mean	SD	Minimum	Maximum
Living room temperature reduction	Switzerland	30	1.85	1.00	-0.13	4.12
	Germany	38	1.39	1.11	-1.61	3.79
	Denmark	34	1.23	1.23	-3.21	3.2
	Finland	33	0.98	0.93	-1.05	2.74
	Hungary	41	0.70	0.96	-1.5	3.08
	Ireland	35	0.21	1.39	-3.57	4.63
	Netherlands	31	0.84	1.16	-0.88	3.82
	UK	23	0.34	1.23	-2.98	2.85
	Total	265	0.95	1.22	-3.57	4.63
Bedroom temperature reduction	Switzerland	30	2.10	1.13	0.54	4.95
	Germany	38	2.05	1.30	-0.48	5.11
	Denmark	34	1.41	0.95	-1.88	3.14
	Finland	32	0.86	0.91	-2.02	2.32
	Hungary	41	0.79	1.18	-2.83	4.00
	Ireland	35	0.62	0.82	-1.00	2.58
	Netherlands	31	2.35	1.19	0.07	5.03
	UK	23	0.89	1.05	-1.23	2.17
	Total	264	1.38	1.25	-2.83	5.11
Weekly laundry cycle reduction	Switzerland	29	30.7	39.0	-57.1	100.0
	Germany	38	16.2	45.1	-180.0	75.0
	Denmark	34	46.1	21.0	-26.5	78.6
	Finland	34	34.4	28.3	-39.7	100.0
	Hungary	41	25.0	29.5	-60.7	70.0
	Ireland	25	12.8	59.1	-250.0	70.0
	Netherlands	29	15.2	34.0	-116.7	60.0
	UK	21	13.3	35.0	-58.2	66.7
	Total	251	25.1	38.3	-250.0	100.0

To test which countries differed from each other I conducted Tukey HSD post-hoc analysis for each dependent variable. The results show, that the differences in **living room temperature reductions** are explained mainly by the high reductions made in Switzerland ($M = 1.85$, $SD = 0.998$) compared to Hungary ($M = 0.70$, $SD = 0.96$, $p =$

0.001), Ireland (M = 0.21, SD = 1.39, p < 0.001), Netherlands (M = 0.84, SD = 1.16, p = 0.013) and the United Kingdom (M = 0.34, SD = 1.23, p < 0.001), and by the high reductions made in Germany (M =1.39, SD = 1.11), compared to Ireland (p < 0.001) and the UK (p = 0.012). The mean differences between the countries and the significances for post-hoc comparisons of living room temperature reductions are presented in Table 5.

Table 5 Mean differences of living room temperature reductions by country (Post hoc comparisons with Tukey HSD, n =265)

	CH	DE	DK	FI	HU	IE	NL	UK
CH	-	0.46	0.63	0.87	**1.15*** **	**1.64*** **	**1.01** **	**1.51*** **
DE		-	0.17	0.41	0.69	**1.18*** **	0.55	**1.05** **
DK			-	0.24	0.53	**1.01** **	0.38	0.88
FI				-	0.28	0.77	0.14	0.64
HU					-	0.49	-0.14	0.36
IE						-	-0.63	-0.13
NL							-	0.50
UK								-

*p < 0.05 **p < 0.01 ***p < 0.001

For **bedroom temperature reductions,** the Tukey HSD test shows that differences between the countries are mainly explained by the same countries as in living room temperatures, but in contrast to the living room temperatures, the highest average reduction in bedroom temperature was made in the Netherlands (M = 2.35, SD 1.19). The average reductions in the Netherlands were 1.72 degrees higher than in Ireland (M = 0.62, SD = 0.82, p = 0.000), 1.55 degrees higher than in Hungary (M = 0.79, SD = 1.18, p < 0.000), 1.49 degrees higher than in Finland (M = 0.86, SD = 0.91, p < 0.000), and 1.46 degrees higher than in the United Kingdom (M =0.89, SD = 1.05, p < 0.000), and 0.94 degrees higher than in Denmark (M = 1.41, SD = 0.95, p = 0.013), The reductions in Switzerland (M = 2.10, SD = 1.12) and Germany (M = 2.05, SD = 1.30) were also higher than in Finland (p < 0.000), Hungary (p < 0.000), Ireland (p < 0.000), and the United Kingdom (p = 0.002). The mean differences for bedroom temperature reductions and the significances of the post-hoc comparisons are presented in Table 6.

Table 6 Mean differences of bedroom temperature reductions by country (Post hoc comparisons with Tukey HSD, n = 264)

	CH	DE	DK	FI	HU	IE	NL	UK
CH	-	0.05	0.69	**1.24*** **	**1.31*** **	**1.47*** **	**-0.25**	**1.21** **
DE		-	0.64	**1.19*** **	**1.26*** **	**1.43*** **	-0.29	**1.16** **
DK			-	0.55	0.61	**0.78**	**-0.94** **	0.52
FI				-	0.06	0.23	**-1.49*** **	-0.03
HU					-	0.17	**-1.55*** **	-0.10
IE						-	**-1.72*** **	-0.27
NL							-	**1.46*** **
UK								-

*p < 0.05 **p < 0.01 ***p < 0.001

For the weekly average **laundry cycle reductions**, the Tukey HSD test shows, that the differences are explained by the high reductions made in Denmark (M = 46.1, SD = 21.0), which were 33.3 percentage points higher than in Ireland (M = 12.8, SD = 59.1, p = 0.017), 30.9 percentage points higher than in the Netherlands (M = 15.2, SD = 34.0, p = 0.024), 32.8 percentage points higher than in the United Kingdom (M = 13.3, SD = 35.0, p = 0.034), and 30.0 percentage points higher than in Germany (M = 16.2, SD = 45.1, p = 0.017). The mean differences in the average weekly laundry cycle reductions between the countries and the significances of post-hoc comparisons are presented in Table 7.

Table 7 Mean differences of laundry cycle reductions by country (Post hoc comparisons with Tukey HSD, n = 251)

	CH	DE	DK	FI	HU	IE	NL	UK
CH	-	14.5	-15.5	-3.7	5.7	17.8	15.5	17.4
DE		-	**-30.0***	-18.2	-8.8	3.3	1.0	2.9
DK			-	11.7	21.1	**33.3***	**30.9***	**32.8***
FI				-	9.4	21.6	19.2	21.1
HU					-	12.2	9.8	11.7
IE						-	-2.4	-0.5
NL							-	1.9
UK								-

*p < 0.05

4.3 Building type

I compared three building type categories: detached houses, semi-detached or terraced houses, and apartment buildings or others. Detached houses had the lowest temperatures in baseline period (20.7°C in living room and 19.4°C in bedroom), semi-detached second lowest (21.3°C in living room and 20.1°C in bedroom) and apartment buildings and other the highest (21.8°C in living room and 21.0°C in bedroom). Baseline and challenge temperatures by building type are presented in Figure 6.

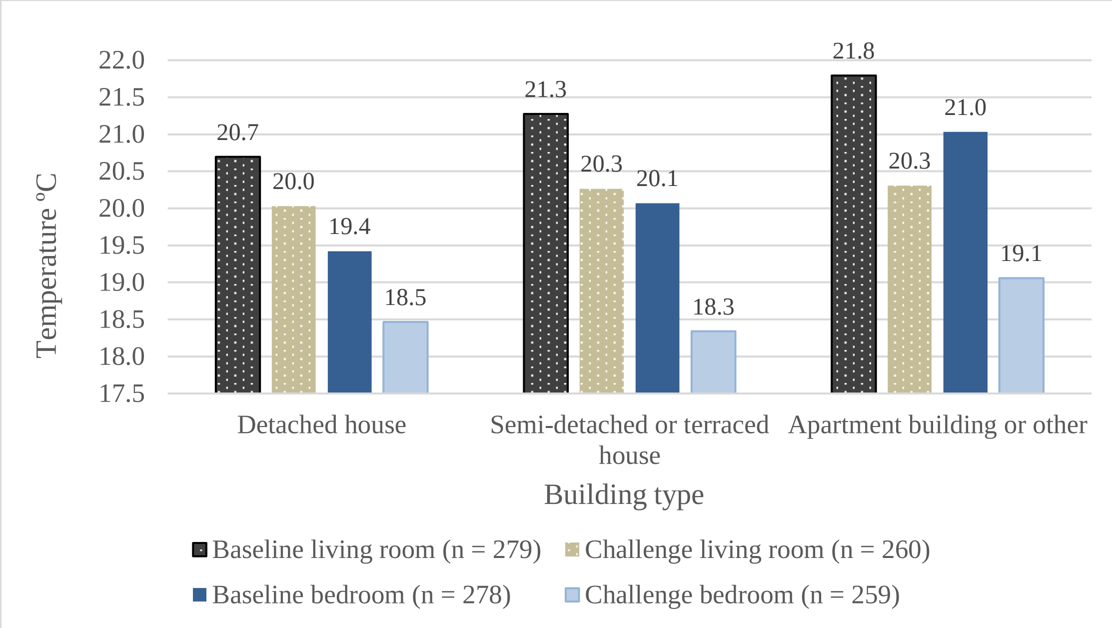

Figure 6 Baseline and challenge temperatures in bedroom and living room by building type

Highest reductions were made in apartment buildings, 1.42 degrees in living rooms and 1.80 degrees in bedrooms, while lowest reductions were made in detached houses, 0.66 degrees in living rooms and 0.95 degrees in bedrooms. The temperatures were reduced more in both living rooms and bedrooms in building types with higher baseline temperatures, as can be seen from Figures 6 and 7. Temperature reductions by building type are presented in Figure 7.

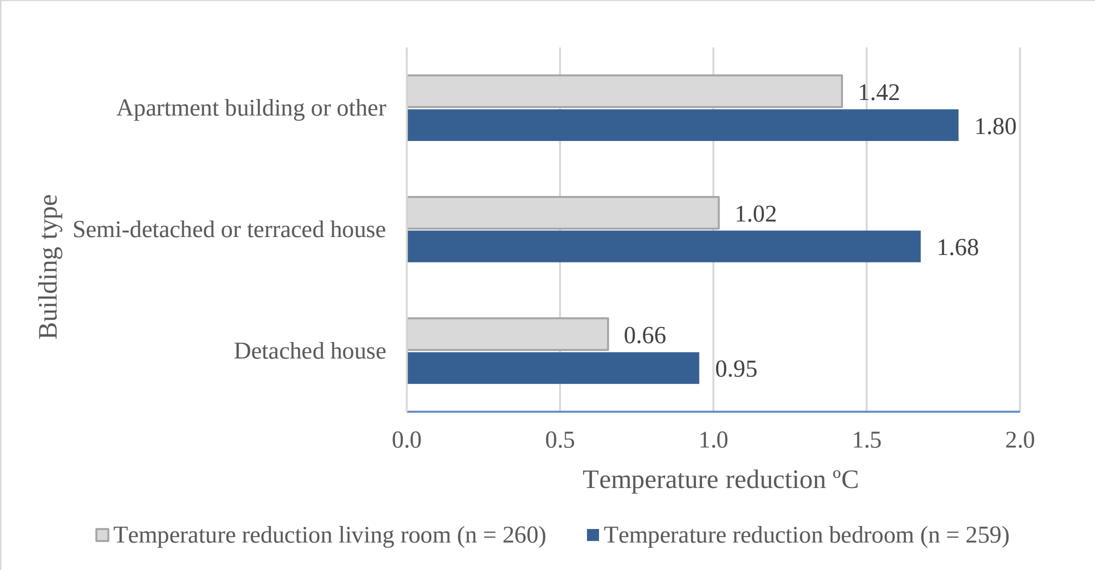

Figure 7 Temperature reductions according to building type in living room and bedroom

The highest weekly average laundry cycles in baseline and challenge periods were measured in detached houses, second highest in semi-detached or terraced houses, and the lowest numbers of laundry cycles were in apartment buildings or others. Number of weekly average laundry cycles in baseline and challenge periods by building type are presented in Figure 8.

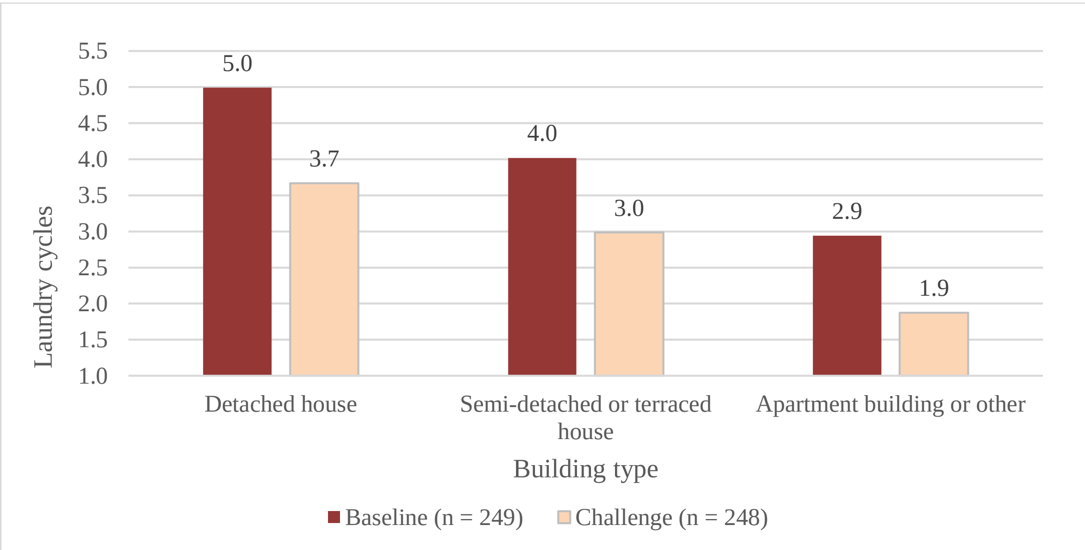

Figure 8 Average weekly laundry cycles in baseline and challenge periods by building type

In apartment buildings and others, the laundry cycles were reduced the most (31.1%), in detached houses a little less (25.7%), while in semi-detached and terraced houses the least (19.0%).

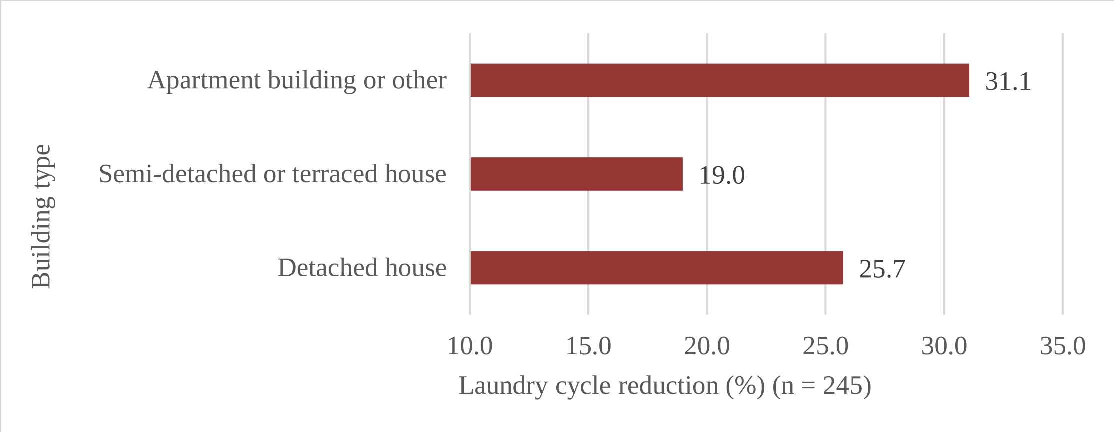

Figure 9 Reductions in the weekly average laundry cycles by building type

I conducted one-way ANOVA tests to compare the intervention outcomes in terms of building type. The results show that there was a statistically significant difference for the three building types in the average reduction of living room temperatures [$F(2, 257) = 8.630$, $p < 0.001$] and bedroom temperatures [$F(2, 256) = 13.643$, $p < 0.001$]. The difference between building types in the average laundry cycle reductions was not statistically significant ($p = 0.158$). The mean reductions and standard deviations by building type are presented in Table 8

Table 8 Means, standard deviations and significances of the ANOVA test of building type

	Temperature reduction living room			Temperature reduction bedroom			Laundry cycles reduction		
	n	Mean (SD)	*p*	n	Mean (SD)	*p*	n	Mean (SD)	*p*
Building type total	*260*	*0.95 (1.22)*	*< .001*	*259*	*1.38 (1.26)*	*< .001*	*254*	*25.0 (38.5)*	*.183*
Detached house	118	0.66 (1.33)		118	0.95 (1.22)		108	25.7 (28.6)	
Semi-detached or terraced house	79	1.01 (1.00)		79	1.68 (1.05)		76	19.0 (51.9)	
Apartment building or other	63	1.42 (1.14)		62	1.80 (1.33)		61	31.1 (33.6)	

To find out which building types differed from each other, I conducted Tukey HSD post-hoc comparisons for temperature reduction in living room and temperature reduction in bedroom. The tests show, that the differences are explained by the smaller reductions made in household living in detached houses. For living room temperatures, households living in detached houses ($M = 0.66$, $SD = 1.33$) reduced temperatures 0.76°C less than people living in apartment buildings or others ($M = 1.42$, $SD = 1.14$, $p < 0.001$. For bedroom temperatures, the test shows that people living in detached houses ($M = 0.95$, $SD = 1.22$) reduced temperatures 0.75°C less than people living in semi-detached or terraced houses ($M = 1.68$, 1.05, $p < 0.001$), and 0.85°C less than people living in apartment building or other ($M = 1.80$, $SD = 1.33$, $p < 0.001$). The mean differences and significances of post-hoc comparisons by building type are presented in Table 9.

Table 9 Post-hoc comparison of building type for living room and bedroom temperature reductions

	Living room temperature reduction (n = 260)			Bedroom temperature reduction (n = 259)		
Building type	Detached house	Semi-detached or terraced house	Apartment building or other	Detached house	Semi-detached or terraced house	Apartment building or other
Detached house	-	-0.36	**-0.76*** **	-	**-0.72*** **	**-0.85*** **
Semi-detached or terraced house		-	-0.40		-	-0.12

***p < 0.001

4.4 Socioeconomic and demographic factors

I analysed the connection of the following socioeconomic and demographic factors to the intervention outcomes: family size, contact person age, contact person education, and contact person occupational status. Table 10 summarizes the results from the analyses of socioeconomic and demographic variables. Each independent variable is then discussed in turn.

Table 10 Mean reductions in laundry cycles and room temperatures according to socioeconomic and demographic characteristics (ANOVA, independent samples t-test)

	Living room temperature reduction			Bedroom temperature reduction			Laundry cycles reduction		
	N	Mean (SD)	*p*	N	Mean (SD)	*p*	N	Mean (SD)	*p*
Family size[a]	*258*	*0.97 (1.22)*	***0.011***	*257*	*1.40 (1.26)*	***0.024***	*243*	*24.8 (38.6)*	***0.011***
1	34	1.40 (1.24)		33	1.70 (1.37)		33	36.3 (27.9)	
2	84	0.91 (1.12)		84	1.48 (1.24)		78	20.0 (41.7)	
3	34	1.34 (1.06)		34	1.46 (1.09)		35	32.7 (30.2)	
4	69	0.85 (1.42)		69	1.44 (1.24)		65	28.9 (30.2)	
5 or more	37	0.55 (1.01)		37	0.79 (1.23)		32	7.43 (54.8)	
Contact person age[a]	*256*	*0.95 (1.22)*	*0.431*	*255*	*1.39 (1.26)*	*0.215*	*242*	*24.96 (38.5)*	***0.034***
25-34	27	1.05 (0.95)		27	1.28 (0.85)		27	30.8 (47.5)	
35-44	61	1.07 (1.14)		61	1.52 (1.35)		61	19.9 (30.0)	
45-54	81	0.95 (1.33)		81	1.43 (1.30)		71	33.3 (28.3)	
55-64	51	0.68 (1.26)		51	1.07 (1.29)		48	12.6 (55.2)	
64-	36	1.10 (1.23)		35	1.65 (1.18)		35	29.1 (30.4)	
Contact person education[b]	*251*	*0.98 (1.23)*	*0.618*	*250*	*1.38 (1.26)*	*0.665*	*238*	*25.4 (39.0)*	*0.701*
Lower	68	1.04 (1.28)		68	1.32 (1.19)		69	23.8 (39.8)	
Higher	183	0.95 (1.22)		182	1.39 (1.29)		169	25.9 (38.8)	
Contact person employment status[b]	*233*	*0.96 (1.25)*	*0.480*	*233*	*1.29 (1.22)*	*0.136*	*220*	*25.2 (39.7)*	*0.523*
Full-time or entrepreneur	143	1.00 (1.14)		143	1.19 (1.12)		136	23.8 (43.4)	
Other	90	0.89 (1.42)		90	1.44 (1.36)		84	27.3 (33.0)	

[a]ANOVA, [b]Independent samples t-test

The baseline temperatures by **family size** varied from 20.9 degrees to 21.5 degrees in living rooms, and from 19.4 degrees to 20.8 degrees in bedrooms. The highest temperatures were measured in families with three persons in both rooms, while the lowest temperatures were measured in households with two persons. In the challenge period, average temperatures in living rooms varied from 19.7 to 20.5 degrees, and in the bedrooms from 17.9 degrees to 19.3 degrees. The highest temperatures in living rooms in challenge period were measured in households with four and five or more persons, while highest temperatures in challenge period in bedrooms in households with three and five or more persons. The lowest living room temperatures were measured in single person households, while the lowest temperatures in bedrooms were measured in two person households. Temperatures in living rooms and bedrooms in baseline and challenge periods by family sizer are presented in Figure 10.

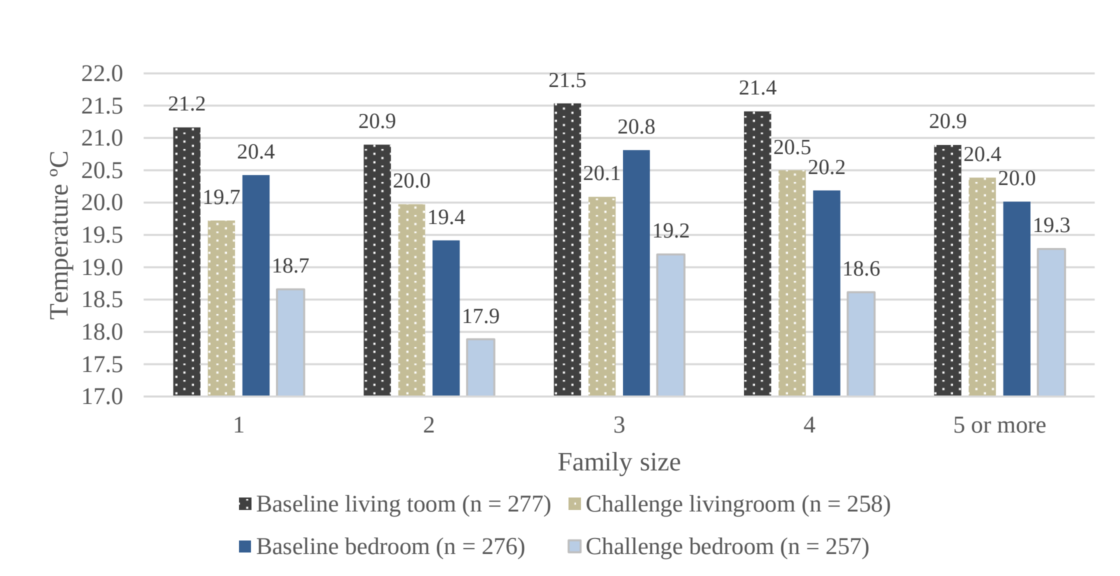

Figure 10 Living room and bedroom temperatures in baseline and challenge periods by family size

Reductions in temperatures according to family size varied from 1.42 to 0.55 degrees in living rooms, and from 1.70 to 0.79 degrees in bedrooms. In general, temperatures both in living rooms and bedroom were reduced more in smaller families (see Figure 11). Households with two persons reduced less their living room temperatures than households with three persons, but this is the only exception.

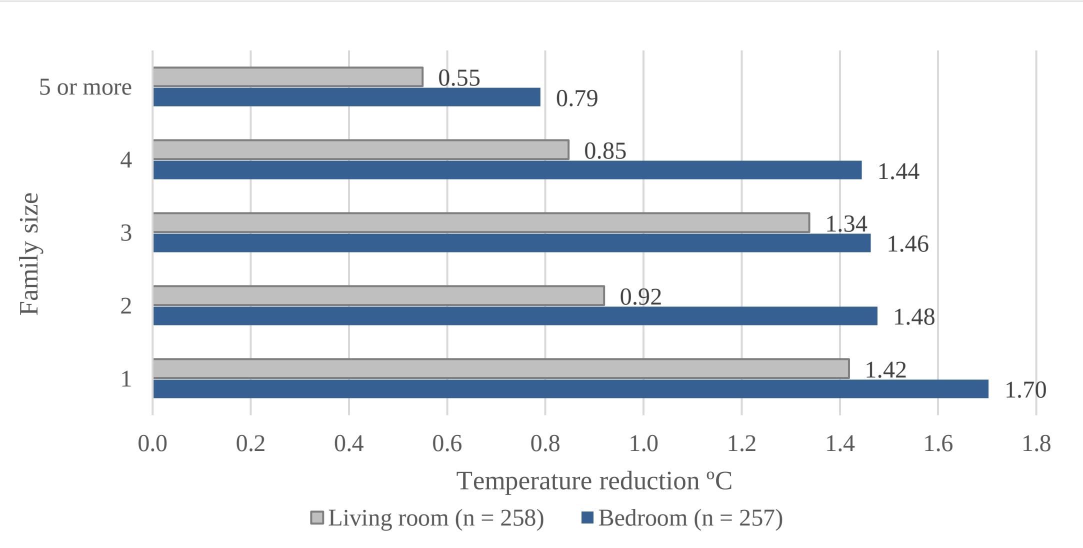

Figure 11 Temperature reductions in living rooms and bedrooms by family size

The number of weekly average laundry cycles by family size varied in baseline period from 2.0 in single households to 5.6 in households with five or more presons, and in challenge period from 1.3 in single households to 4.7 in households with five or more persons. As can be seen from Figure 12, the number of weekly average laundry cycles during baseline and challenge periods were in line with family size.

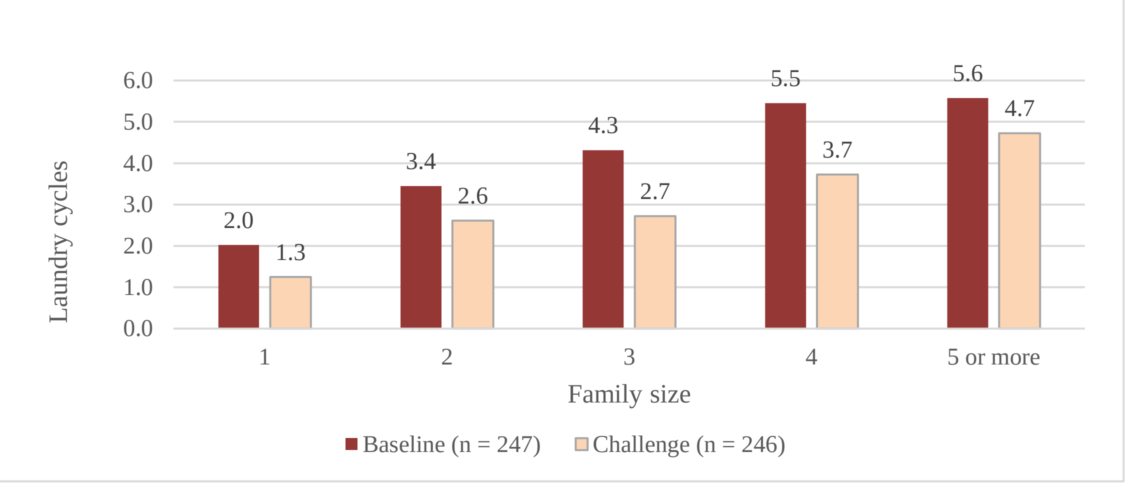

Figure 12 The number of weekly average laundry cycles in baseline and challenge periods by family size

The reductions made in average weekly laundry cycles during challenge period ranged from 36.3% in single households to 7.4% in families with five or more persons. In general, the smaller the family, the greater were the reductions made. Similar to living room temperature reductions, families with two persons were an exception as can be seen from Figure 13.

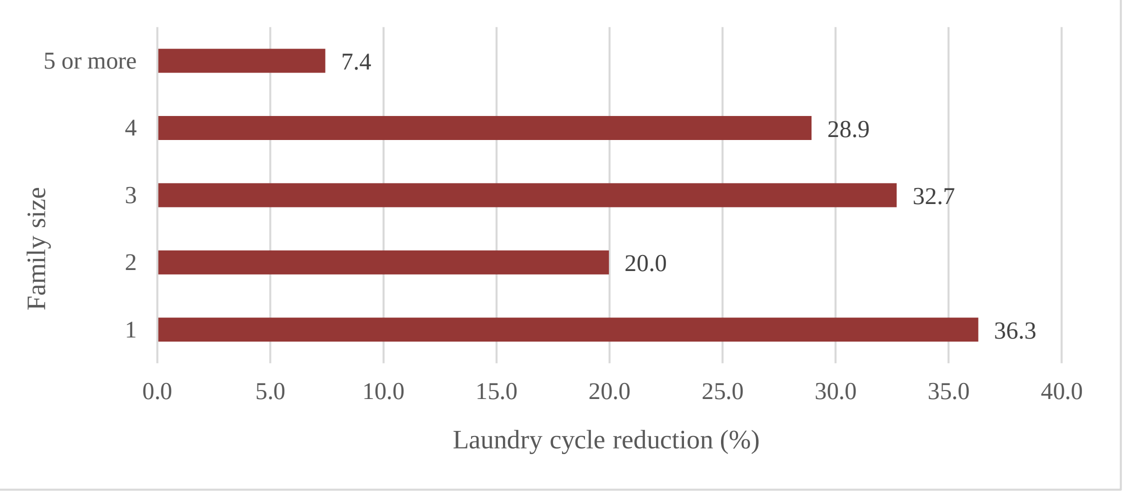

Figure 13 Reductions (%) in the number of weekly average laundry cycles by family size

I ran a one-way ANOVA to test if there were statistically significant differences between the family sizes in the temperature and the laundry cycle reductions. The results show, that there were statistically significant differences according to family size for each dependent variable: living room temperature reduction [$F(4, 253) = 3.316$, $p = 0.011$], bedroom temperature reduction [$F(4, 252) = 2.865$, $p = 0.024$], and the average reduction of weekly laundry cycles [$F(4, 238) = 3.340$, $p = 0.011$]. I conducted Tukey HSD post-hoc comparisons to see which family sizes differed from each other. The results show, that the differences are mainly due to families with five or more persons reducing less in temperatures and laundry cycles than smaller families (see Table 11 for mean differences between the family sizes, and the significances of post-hoc comparisons).

Table 11 Tukey HSD post-hoc comparisons according to family size

	Living room temperature reduction (n = 258)				Bedroom temperature reduction (n = 257)				Laundry cycle reduction (n = 243)			
Family size	2	3	4	5 or more	2	3	4	5 or more	2	3	4	5 or more
1	0.50	0.08	0.57	**0.87***	0.23	0.24	0.26	**0.91***	16.3	3.6	7.4	**28.9***
2	-	-0.41	0.07	0.37	-	0.01	0.03	**0.69***	-	-12.7	-9.0	12.5
3		-	0.49	**0.79***		-	0.02	0.67		-	3.8	25.3
4			-	0.30			-	0.65			-	21.5

*p < 0.05

The baseline weekly average laundry cycles by **contact person age** ranged from 3.0 in households with contact person aged 65 or older to 4.9 in households with contact person aged 35-44. In the challenge period, the number of weekly average laundry cycles ranged from 2.1 in households with contact person aged 65 or older to 3.8 in households with contact person aged 35-44 years.

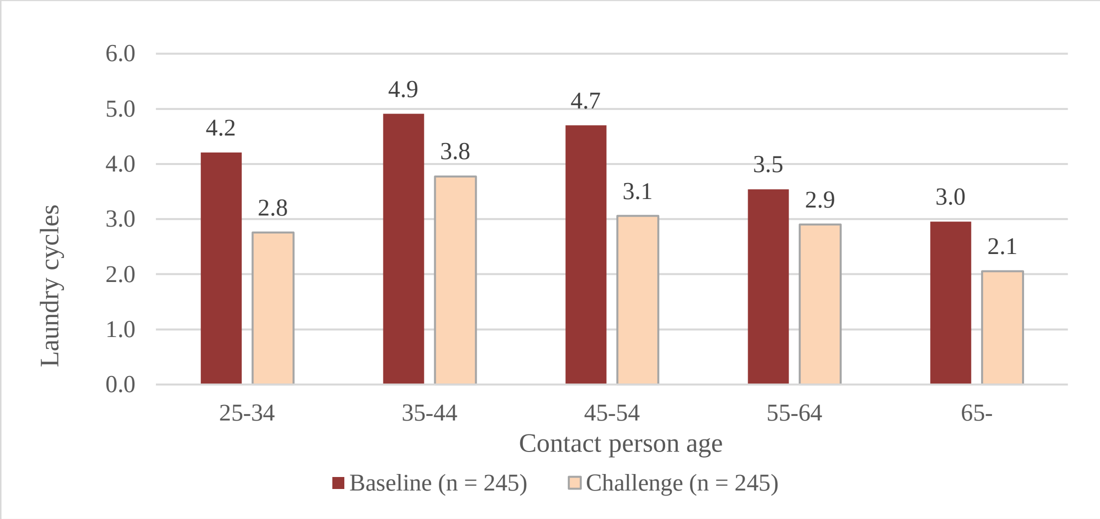

Figure 14 Number of weekly average laundry cycles in baseline and challenge periods by contact person age

The laundry cycle reductions by contact person age varied from 12.6% in households with contact person aged 55-64 to 33.3% in households with contact person 45-54 years of age. There appeared not to be any linear relationship between contact person age category and the reduction in average weekly laundry cycles, as can be observed from Figure 14.

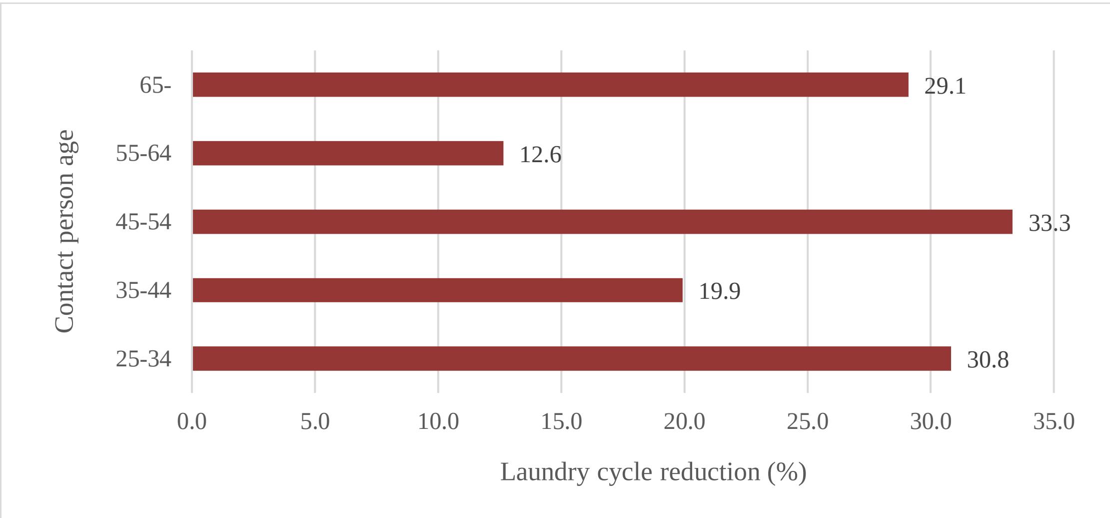

Figure 15 Reductions in the number of weekly average laundry cycles by contact person age

For contact person age groups the one-way ANOVA results show that the households differed from each other in terms of laundry cycle reduction ($F(4, 237) = 2.647$, $p = 0.034$), but not according to living room temperature reduction ($p = 0.431$) or bedroom temperature reduction (p = 0.215). To determine which age groups differed from each other in terms of laundry cycle reductions I conducted Tukey HSD post-hoc comparisons. The results show that households with contact person aged 55-64 (M = 12.6, SD = 55.2) made a 20.7 percentage points lower reduction in their average weekly laundry cycles than the age group 45-54 (M = 33.3, SD = 28.3, p = 0.032).

Table 12 Post-hoc comparisons for contact person age: mean differences and significance

	Laundry cycles reduction				
Contact person age	25-34	35-44	45-54	55-64	64-
25-34	-	10.9	-2.5	18.1	1.7
35-44		-	-13.4	7.3	-9.2
45-54			-	**20.7***	4.2
55-64				-	-16.4

*p < 0.05

For **contact person education** variables, the independent samples t-test shows, that the difference between higher education and lower education group was not statistically significant according to any of the dependent variables: living room temperature reduction, t(249) = 0.499, p = 0.618; bedroom temperature reduction, t(248) = -0.434, p = 0.665; laundry cycle reduction, t(236) = -0.385, p = 0.701. Similarly, the independent samples t-test for **contact person employment status** shows, that employment status was not connected to intervention outcomes: living room temperature reduction, t(231) = 0.707, p = 0.480; bedroom temperature reduction, t(231) = -1.497, p = 0.136; laundry cycle reduction, t(218) = -0.640, p = 0.523.

4.5 Baseline temperatures and baseline laundry cycles

I conducted correlation analyses to study the connections of two interval variables. Based on the literature review and the analysis of categorical variables I included the following independent variables: baseline temperature in living room and bedroom, baseline weekly average laundry cycles, and thermal comfort in bedroom and living room. Correlation analysis results show that there was a positive correlation between baseline temperature in living room and temperature reduction in living room ($r = 0.393$, $n = 265$, $p < 0.001$), but not a statistically significant correlation between baseline temperature in bedroom and temperature reduction in bedroom ($r = 0.082$, $n = 264$). For laundry cycles, there was a positive correlation between baseline weekly average laundry cycles and reduction in weekly average laundry cycles ($r = 0.168$, $n = 251$, $p = 0.008$). A positive correlation was also found between living room temperature reduction and bedroom temperature reduction ($r = 0.566$, $n = 264$, $p < 0.001$), as well as between laundry cycles reduction and living room temperature reduction ($r = 0.264$, $n = 241$, $p < 0.001$), and laundry cycles reduction and bedroom temperature reduction ($r = 0.131$, $n = 240$, $p = 0.042$). All correlation coefficients and significances are presented in Table 14.

Table 13 Correlation coefficients (Pearson) and statistical significances

	Baseline temperature living room	Baseline temperature bedroom	Temperature reduction living room	Temperature reduction bedroom	Baseline laundry cycles	Laundry cycle reduction
Baseline temperature living room	1	0.739**	0.393**	0.162**	0.003	0.121
Baseline temperature bedroom		1	0.272**	0.082	-0.072	0.125*
Temperature reduction living room			1	0.566**	-0.143*	0.264**
Temperature reduction bedroom				1	-0.137*	0.131*
Baseline laundry cycles					1	0.168**
Laundry cycle reduction						1

***$p < 0.001$ **$p < 0.01$ *$p < 0.05$

4.6 Multiple regression models

Based on the analysis I conducted in the first phase with independent variables, I formed linear regression models for each dependent variable. I created three multiple linear regression models, one for each dependent variable. For living room temperature reduction and bedroom temperature reduction, I included the following variables[3]: baseline temperature, thermal comfort, country, building type and family size. A significant equation was found both for living room temperature reduction [$F(15, 230) = 5.033$, $p < 0.001$], and bedroom temperature reduction [$F(15, 224) = 7.549$, $p < 0.001$]. The variables in the model explain 26% ($R^2 = 0.26$) of the variance in the data for living room temperature reduction, and 33% ($R^2 = 0.33$) for bedroom temperature.

The results show that higher room temperatures during the baseline period were connected to higher reductions in the challenge period. For living room temperatures, an increase of 1 degree in baseline temperature resulted on average a 0.22 degrees higher reduction, when the effects of country, building type and family size were standardised. For bedrooms, the figure was slightly smaller, 0.12 degrees. For living room temperature reductions, the results show that households in Switzerland reduced on average 0.86 degrees more, and households in Germany on average 0.62 degrees more than households in the reference group of Hungary when the effect of other variables in the model were standardised. Similarly, with regard to bedroom temperatures, households in Switzerland reduced on average 1.25 degrees more, and in Germany 1.35 degrees more than households in the comparison group of Hungary. For bedroom temperatures, the result for the Netherlands was also statistically significant resulting on an average 1.8 degrees higher reduction than in the reference group. Households with five or more persons reduced their bedroom temperatures on average 0.54 degrees less than the reference group of two-person households, when the effect of the other variables in the model were standardised. The results for family size were not statistically significant in the model of living room temperature reductions. Building type variable was not statistically significant in either of the temperature reduction models.

[3] Although the correlation between bedroom baseline temperature and bedroom temperature reduction was not statistically significant, I decided to include it in the model, because there was a relationship between baseline temperatures and challenge temperature in the living rooms. The inclusion of the variable also increased the model's multiple coefficient of determination (R^2).

Table 14 Regression coefficients, standard errors and significances for living room and bedroom temperature reductions

	Variable	Living room temperature reduction (n = 257)			Bedroom temperature reduction (n = 256)		
		B	*SE B*	*β*	*B*	*SE B*	*β*
	Baseline temperature	**0.22**	**0.06**	**0.29*****	**0.12**	**0.05**	**0.19****
Country	Switzerland	**0.86**	**0.34**	**0.22****	**1.25**	**0.33**	**0.31*****
	Germany	**0.62**	**0.26**	**0.18****	**1.35**	**0.27**	**0.38*****
	Denmark	0.39	0.26	0.11	0.45	0.26	0.12
	Finland	0.04	0.27	0.01	-0.03	0.27	-0.01
	Hungary	(a)			(a)		
	Ireland	-0.09	0.27	-0.03	0.25	0.29	0.07
	Netherlands	0.32	0.30	0.08	**1.80**	**0.32**	**0.46*****
	UK	-0.12	0.32	-0.03	0.05	0.30	0.01
Building type	Detached house	(a)			(a)		
	Semi-detached house	0.10	0.19	0.04	0.23	0.18	0.09
	Apartment building	0.01	0.24	0.00	-0.05	0.24	-0.02
Family size	1	0.44	0.23	0.12	0.11	0.23	0.03
	2	(a)			(a)		
	3	0.22	0.23	0.06	-0.18	0.22	-0.05
	4	-0.28	0.18	-0.10	-0.20	0.18	-0.07
	5 or more	-0.24	0.23	-0.07	**-0.54**	**0.22**	**-0.15****
	Constant	-3.99			-1.53		
	R^2		0.26			0.33	

**p* < .05. ***p* < .01. *** p < 0.001
(a) reference category

A significant equation was also found for laundry cycle reduction [F(16, 225) = 4.471, p < 0.001]. The variables included in the model explain 24% ($R^2 = 0.24$) of the variance in the dependent variable of laundry cycle reductions. The results show that higher baseline weekly average laundry cycles resulted in higher reductions. On average, an increase in the baseline weekly laundry cycles by 1 resulted in a 5.2 percentage points higher reductions in the challenge period when the effects of country, family size and contact person age were standardised. Other factors being constant, households in

Denmark reduced their weekly average cycles 25 percentage points more compared to the reference group of Hungary. The model also shows that single person households reduced 20.0 percentage points more laundry compared to the reference group of 2-person households, while families with five or more person reduced 23.4 percentage points less compared to two-person households, other factors being standardised. According to the model, households with contact person aged 55-64 reduced 16.7 percentage points less laundry compared to age category of 45-54 years, when the effect of baseline cycles, country and family size was standardised.

Table 15 Regression coefficients, standard errors and significances for laundry cycle reductions

		Weekly average laundry cycles reduction (n = 242)		
	Variable	*B*	*SE B*	*β*
	Baseline weekly average laundry cycles	**5.22**	**1.16**	**0.34****
Country	Switzerland	13.11	9.47	0.10
	Germany	-5.98	8.38	-0.06
	Denmark	**25.00**	**8.40**	**0.23****
	Finland	8.24	8.52	0.07
	Hungary	(a)		
	Ireland	-15.75	9.14	-0.12
	Netherlands	-5.03	8.98	-0.04
	UK	-8.92	9.93	-0.06
Family size	1	**20.00**	**7.57**	**0.18****
	2	(a)		
	3	3.33	7.67	0.03
	4	-5.99	7.29	-0.07
	5 or more	**-23.40**	**8.53**	**-0.21****
Contact person age	25-34	1.82	8.03	0.01
	35-44	-6.44	6.42	-0.07
	45-54	(a)		
	55-64	**-16.70**	**7.12**	**-0.17***
	65-	-2.76	8.00	-0.03
	Constant	7.24		
	R^2		0.24	

*$p < .05$. **$p < .01$.
(a) reference category

5. Discussion

Overall, the ENERGISE intervention can be considered successful. Households reduced their living room temperatures on average by 0.95°C compared to baseline period, and the bedroom temperatures by 1.38°C. Households reduced their weekly average laundry cycles on average by 25.1%. There were, however, contextual factors that were in connection with the variation in the intervention outcomes. In this chapter, I analyse the results presented in the previous chapter by first discussing them in connection to the three contextual perspectives, national and cultural context, material and institutional context, and socioeconomic and demographic context. I then evaluate the reliability of the data and the results, and finally provide a summary of the discussion.

5.1 Geographical and cultural context

One central aim of my thesis was to examine if there were differences between national contexts in the outcomes of the interventions. The results presented in the previous chapter indicate that the outcomes did vary between the countries. The temperature reductions in living rooms ranged from 1.85°C in Switzerland to 0.21°C in Ireland, and in bedrooms from 2.35°C in the Netherlands to 0.62°C in Ireland. The analysis of the main effects suggested that there were statistically significant differences between the households in countries that reduced the most and the households in countries that reduced the living room and bedroom temperatures the least. The regression models provided further evidence of national differences in the temperature reductions. When the effect of baseline temperature, building type and family size were standardised, households in Switzerland reduced their living room temperature 0.86 degrees more than the reference group of Hungary, and households in Germany 0.62 degrees more than the reference group. For bedrooms, households in the Netherlands reduced the temperatures the most, and the reductions were 1.8 degrees higher than reductions in households in the reference group of Hungary. The results were statistically significant also for Switzerland (1.35 degrees higher than in the reference group) and Germany (1.35 degrees higher than in the reference group). The significance of the national context was thus similar in both living room and bedroom temperatures, except for the high reductions of bedroom temperatures in the Netherlands.

There were also cross-national differences in the laundry cycle reductions. The highest reductions in weekly laundry cycles were observed in Denmark (46%), and when looking at the main effects, this reduction was statistically significantly greater than in Ireland (12.8%), UK (13.3%), The Netherlands (15.2%) and Germany (16.2%). The analysis with the multiple regression model provided similar results: when the effect of baseline laundry cycles, family size, and contact person age were standardized, households in Denmark achieved 25 percentage point higher reductions compared to households in the reference group of Hungary.

In the ENERGISE intervention there thus appeared to be variation in the outcomes that can be attributed to national contexts. Previous research has demonstrated that countries within Europe differ from each other in terms of energy consumption (e.g Laakso & Heiskanen 2017; Vávra et al. 2015). As the literature review suggests, there are multiple factors that can contribute to the differences between countries observed in this study. Thermal comfort has been shown to vary according to a variety of factors, such as perception of control over thermal setting, but also between different cultural contexts (Sahakian and Naef 2019; Brelih 2013). National guidelines for optimal room temperatures vary within Europe (Brelih 2013), which is likely to affect room temperatures in general, but possibly also to the intervention outcomes. Baseline temperatures in living rooms varied from 19.7 degrees in Ireland to 22.3 degrees in Switzerland, and in bedrooms from 17.5 degrees in Ireland to 21.8 degrees in Switzerland. The variation in baseline temperatures between countries is in line with previous research (e.g. Vávra et al 2015) and supports the observations that room temperatures in central Europe and the Nordic countries tend to be higher than for instance in the United Kingdom. Cultural differences in thermal comfort and national guidelines about optimal room temperatures may thus be affecting the differences observed in this study. Similarly, there might also be cultural and national differences in more material elements such as energy systems or technological differences in heating systems.

As outlined in the description of the ENERGISE research project, each country had their individual research teams, who conducted the implementation of the living labs and collected the research data. Although the implementation and intervention execution were planned on the project level, there likely have been some differences in the processes between the countries. For instance, the community support or the individual visits by the researcher with the households may have been more productive and supportive in some countries than others. I have not compared the intervention outcomes between the two living laboratories in the present thesis, but according to another study (Matschoss et al. forthcoming) we conducted, the differences between individual and community living labs were not particularly high. However, we did not compare the living labs in different countries due to small number of data in some of the countries, but it might be that the outcomes of individual and community living labs did vary according to the national context. Hence, in addition to cultural differences in the practices and conventions, there may have been national differences in the implementation of the interventions themselves.

5.2 Material and institutional context

Material and institutional factors, such as building type or energy systems, have been shown to be important factors both enabling and restricting energy saving behaviour. I analysed the connection of building type to the intervention outcomes. The analysis of main effects in temperature reductions showed that families living in detached houses reduced the temperatures less than families living in the other two building types, semi-detached or terraced houses, and apartment buildings. Interestingly, however, in the multiple regression models for living room and bedroom temperature reductions, building type was not statistically significantly connected to the intervention outcomes. Further inspection of the analysis and the baseline temperatures by building type suggest that the baseline temperatures could explain why building type initially appeared to be connected to temperature reductions. Rather expectedly, reductions in the average weekly laundry cycles did not differ in the three building types. There are likely other material and institutional factors, which are more relevant to laundry washing, such as the energy systems, but laundry washing may also be a practice, which is less dependent on such factors. The washing machines, for instance, are rather similar in all of Europe, and the differences are more likely attributable to cultural differences in practices or family demographics, for instance.

The analysis of the main effects indicated that baseline temperatures might be connected to the intervention outcomes. There was a positive correlation ($r = 0.393$, $p < 0.001$) between the baseline temperature in living rooms, and temperature reduction in living room temperatures, but the correlation between bedroom temperature reductions and baseline temperatures was very low and not statistically significant ($r = 0.082$, $p = 0.182$). However, in the multiple regression models, both living room and bedroom baseline temperatures were statistically significantly connected to the intervention outcomes. On average, households that had a one degree higher baseline temperature in living room, made 0.22 degrees higher reduction during the challenge period. For bedrooms the effect wassmaller, 0.12 degrees. Similar observations can be made with regard to weekly average laundry cycles. Although the correlation ($r = 0.168$, $p = 0.008$) between the baseline weekly average laundry cycles and the average weekly laundry cycle reductions was not high, the regression model indicated that when controlling for the effect of country, family size and contact person age, higher number of baseline laundry cycles resulted in higher reductions during the challenge period. An increase in the number of weekly average baseline laundry cycles by one resulted in an increase of 5.2 percentage points in laundry cycles reductions. These observations suggest that participants who have initially paid less attention to frugality in laundering and home heating perceive more opportunities for reductions than those who were already relatively frugal before the start of the intervention. This is in line with the suggestion made by Šćepanović et al. (2017) that households already efficient in energy consumption might be restricted in their actions, receives support from the observations made in this study.

5.3 Socioeconomic and demographic context

I analysed the connection of socioeconomic status to the intervention outcomes with variables of contact person's educational level and contact person's employment status. According to my analyses, the intervention outcomes did not vary in terms of household contact person education, or in terms of contact person employment status. Previous research has found ambiguous results of the connection of socioeconomic status and household energy behaviour. Employment status has been little addressed in household energy consumption research and intervention studies, and the results on educational level have been contradictory (cf. Belaïd and Garcia 2016; Pothitou et al. 2017). Šćepanović et al. (2017) suggested that 'vulnerable' households have often been less motivated and committed to interventions, but on the other hand, Abrahamse and Steg (2009) concluded in their study that intervention outcomes were not dependent on the socioeconomic status. It can be concluded, that socioeconomic status did not predict intervention outcomes in this study, and while some previous studies have found socioeconomic differences in the intervention outcomes and energy conservation behaviour, the results from my study support the observations that socioeconomic status is not a strong predictor of changing energy behaviour. It is of course important to keep in mind that the data in this thesis represents the household contact person's education level (except for Ireland, as noted earlier) and employment status, and this might not be the same person who is taking care of laundry or adjusting temperatures. In addition, these variables do not reflect who and how many family members actively engaged themselves with the challenges.

Family size appeared to be a significant factor in both temperature reductions and laundry cycle reductions. The single person households reduced their living room and bedroom temperatures the most (on average 1.4 degrees in living rooms and 1.7 degrees in bedrooms), while the biggest families, i.e. families with five or more persons reduced the temperatures the least (on average 0.55 degrees in living room and 0.79 degrees in bedroom). When controlling for the baseline temperature, thermal comfort, country, and building type, households with five or more persons reduced their bedroom temperatures 0.54 degrees less than the control group of two-person households. For living room temperatures, the effect of family size was not statistically significant in the regression model. When looking at the laundry cycles, the results present a very similar picture of the relationship between family size and the intervention outcomes. Single person households reduced the most, 36.3% of their average weekly laundry cycles compared to baseline period, and the biggest families with five or more persons the least, 7.4%. The multivariate analysis showed, that single family households reduced 20.0 percentage points more in their weekly average laundry cycles, and families with five or more persons 23.4 percentage points less than the control group (two persons), when the effect of baseline laundry cycles, country and contact person age were standardized. The intervention outcomes in big families were thus poorer than in smaller families, and in particular those of single households. Outcault et al. (2018)

studied social dynamics in an energy intervention and found that the contact persons found it difficult to coordinate the actions in households with several members. Similar to Belaïd and Garcia's (2016) study, the participants in the Outcault et al's (2018) study stated that the comfort of other household member, in particular children, affected their energy saving behaviour. In single-person households neither coordination challenges nor consideration for others' comfort are not as relevant.

Contact person age was not a strong predictor of intervention outcomes in this study, but there was a statistically significant relationship between age and the laundry cycle reductions. Households in which the contact person was 55-64 years of age reduced the least (12.6%) in their weekly laundry cycles, and the reduction was 22.7 percentage points lower than reductions in the age category of 45-54 (33.3%). The regression analysis supports this finding: households with a contact person aged 55-64 reduced 16.7 percentage points less in their laundry cycles than the reference age group of 45-56, when the effects of baseline weekly cycles, country, and family size were standardized. The relationship of smaller reductions and the contact person age group of 55-64 is rather surprising in light of the literature review. For instance, Belaïd and Garcia (2016) found in their study that adults aged 28-45 of age engaged less in household energy-saving practices than other age groups, likely due to having young family members. It is perhaps more likely that the reasons behind this result are explained by factors that were not analysed in this thesis and perhaps directly related to the practice under study, laundry washing. For instance, because contact persons in this age group are still likely in working life, as opposed to the age group of 65 years and older, they need clean clothes for work. Possible children would already be grown-up likely having similar needs in terms of clean clothing. Some other factors, such as having certain types of work involvement, having houseguests during the intervention, having persons in the family needing extra care, could make it more difficult to reduce laundry cycles (cf. Alborzi et al 2017; Strengers et al. 2016; Balaïd and Garcia 2016)

5.4 Evaluating the reliability of the results

The data used in this study was a non-randomized sample with in total 306 respondents, and the results are therefore not extendable to population at large. There are two main reasons enhancing the reliability of the data in general. Firstly, the data was collected individually in each country and each research team became well acquainted with their own participants as well as the data they collected. The researchers further examined the data during each country's country-specific data analysis. Secondly, during the combining process, I myself became familiar with the data and was able to notice some missing and inaccurate data and complement and correct them. On the other hand, the internal validity of the data might be affected by the separate collection processes and by the large number of researchers involved in the data collection.

There were missing values in the database, which affected the number of valid cases in the analyses. This affected especially the regression analysis which included several variables, and adding more variables (such as the non-significant variables analysed in the first phase) would have further lowered the number of valid cases in the analysis which were already rather low (240-257 out of 306). For instance, the data on ownership type was almost completely missing from the Netherlands. T For a more in-depth understanding of the complexity of contextual factors a comparison of, for example, the effect of different family sizes in different countries would have been very interesting, but this kind of analysis was not possible as the compared groups would have been too small.

The data used in the dependent variables were self-reported; the room temperatures were taken from the weekly surveys households filled in weekly during the baseline and challenge periods, and the weekly laundry cycles were calculated from the laundry diaries the households kept during the baseline and challenge periods. Self-report data could entail some problems with the reliability, such as misplaced thermometers or reporting temperatures or laundry data based on memory (in case the respondents forgot to report them on time). There were, however, measures taken in order to increase the reliability of the self report data. For instance, the thermometers were placed in the apartment together with the researchers, and the households were informed on how to keep the laundry diaries during visits at the participants' homes. The dependent variables on temperatures were based on average temperatures during baseline and challenge. All respondents who provided at least one measure during the period were included in the analysis, and some values are based on only a few figures. The number of such cases is nevertheless low, less than 10 in each of the dependent variables.

Reductions in indoor temperatures might be dependent on the concurrent reduction in outdoor temperatures, given the timing of the project. However, the intervention was found to have an independent effect and hence reductions in indoor temperatures are not merely due to declining outdoor temperatures (Heiskanen et al. 2019b; Harries et al. 2019). It is also worth noting, that in international comparisons such as the present study, compromises have to be made when deciding on the categorizations of the variables in order to make them fit every country's situation. There may thus be issues with the internal validity in some of the dependent variables, such as educational level or building type.

5.5 Summary of the analysis

The results in this thesis about the intervention outcomes of living room and bedroom temperatures and laundry cycle reductions show that a variety of contextual factors were connected to the successfulness of the interventions. Country, baseline temperatures and family size were explaining the variance in temperature reductions. Interestingly, the connection discovered in the first phase of the analysis between building type and the temperature reductions was explained by other factors, most likely baseline temperatures. The analysis of main effects indicated that baseline laundry cycles, country, family size, and contact person age were explaining the variance found in the outcomes of laundry washing challenge. Further analysis with the multiple regression model showed, that even after standardizing the variables, these factors were connected to the laundry cycle reductions.

When analysing the results from the perspective of the household practices under study, space heating and laundry washing, there are both similarities and differences in terms of which contextual elements are explaining the variance in the results. As the literature review indicated, the material and institutional context seems to be less significant in the reduction of laundry cycles. The basic material factors connected to laundry washing are rather similar in Europe, such as the technical elements of washing machines. What, on the other hand was more significant in the practice of laundry washing were the demographic characteristics of age and family size, although family size was also connected to temperature reductions in the bedroom. The baseline temperature and laundry cycles were significant in both practices, and one important implication from this study is that, although it seems rather self-evident, the largest opportunities for reductions in energy consumption are with the highest consuming households.

The purpose of this analysis has not been to provide a comprehensive model, but rather identify some of the contextual (external) factors, that may be significantly affecting the successfulness of household energy intervention outcomes to increase understanding of what is important to take into consideration when planning and implementing behaviour change interventions. The data sample used is rather small, but the reliability of the data was evaluated and improved throughout the entire ENERGISE research project. Given the purposes of this paper, the data can be evaluated as being sufficient and there were no major issues that would have significantly affected the reliability of the results.

6. Conclusions

The urgent need to reduce emissions requires actions in all sectors, from transportation and industry to the residential sector. Households are consuming a relatively large amount of final energy, and the requirement for reductions has been addressed, among other things, through research on residential energy use. Several scholars have recognised the importance of contextual factors in household energy interventions, but there still exists a considerable gap in research. Even though, as Heiskanen et al. (2019a) point out, context is not only relevant to the outcomes of the intervention, but also to the transferability and scalability of the interventions, there is still very little research taking the contextual factors at its focus. Additionally, comparative intervention studies between multiple national contexts are almost non-existent. In this thesis, I have evaluated the role of context in a multinational household energy intervention project and provided insight into these areas given far too little attention so far.

What is meant by context in household energy interventions depends on the purpose of the study and the research tradition from which it is studied. In this thesis, I have treated context as factors external to the intervention design. Based on previous research I decided to analyse the context from three perspectives: national and cultural context, material and institutional context, and socioeconomic and demographic context. This categorisation combines elements from several studies and was built with the intention to serve my specific research objectives and the data that was available. The analyses I conducted and the results obtained support the observations made based on previous research that many of the contextual factors are closely linked to each other and overlapping, and thus assigning them to certain categories is not self-evident.

The purpose of the present thesis was to investigate the role of context in household energy interventions. Overall, the results suggest that various contextual factors, such as geographical, material and institutional, and demographic contexts may have significant effect on the outcomes of domestic energy interventions. The intervention outcomes differed in some of the geographical contexts, even after a number of other factors were controlled for. The baseline levels of consumption were important predictors of intervention outcomes in both household practices. These levels are likely affected by i.e. material factors, such as type of the dwelling, family demographics, as well as cultural conventions and habits. Big families provided poorer results than small families in both interventions, while the contact person's age was only connected to the laundry cycle reductions.

These findings have significant implications for the planning of future interventions. Firstly, the results suggest that different household energy practices are likely to be affected by different set of contextual factors. These findings add on to the complexity of designing effective interventions, as the intervention outcomes are affected by not only a set of contextual factors and intervention strategies, but also the practices that are to be changed. Secondly, although not often discussed in household energy consumption and intervention literature, the consumption levels prior to the intervention significantly affect households' abilities to make reductions. The future interventions should therefore be targeting high consuming households. Considering the role of context in designing interventions is thus important not only for the intervention outcomes, but also for their scalability and transferability in local, national and international level.

This study has also demonstrated that conducting cross-national research is not an easy task, but rather a task that requires careful planning and execution in which the requirements of comparability of the data are considered throughout the research process, while at same time being sensitive to the national and cultural characteristics of each country. The technical task of combining data from different data files sets requirements for the format, otherwise the task can become extremely time consuming, or it might lead to compromises between amount of times used in the data preparation and the number of variables included in the combined data set. Cross-national comparisons are challenging due to many reasons, and sometimes the differences within a country are greater than the differences between countries. Perhaps this complexity of cross-national comparisons is also one reason to its lack in research. This thesis has provided some insight into the cross-national differences in household energy interventions, but additional research in is still required to shed more light into the specific components behind the national differences.

The results on socioeconomic context showed, that education and employment status were not explaining the differences in the intervention outcomes. These observations are, for the most part, in line with previous research, which suggest that the relationship between socioeconomic status and intervention outcomes is not clear. However, there has been little research on these factors, and therefore I suggest, that the role of socioeconomics (other than just income), should be more thoroughly researched in the future, although it might be that factors, such as cultural conventions, material factors and intervention strategies are much more central to the successfulness of the intervention than socioeconomics.

Another consideration for future research is the role of participants' age in energy interventions. Some studies have found that young and old are more engaged in energy saving practices, than others, likely due to having young children in the family. The results from my thesis do not support this observation, as the households with contact persons aged 55-64 reduced the least in their weekly laundry cycles. The analysis, however, indicate, that the explanation to the result may lie at the practice under study. Future research could thus investigate the results of interventions in terms of the practice, and perhaps compare the different contextual factors relevant to different household energy practices.

The whole complexity of contextual factors is difficult to address in one research project. It would have been very interesting to compare for instance family sizes or age groups in different countries to generate a more comprehensive picture of the contextual factors' interplay, but the resulting groups would have been too small to provide statistically significant analysis in this study. However, this would be yet another theme for future research. It however, would require a larger number of respondents, but on the other hand, the data collected could be more focused on the contextual factors, thus requiring a smaller set of variables.

References

Abrahamse. W., Steg. L., Vlek. C., & Rothengatter. T. (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology, 25,* 273-291.

Abrahamse, W., & Steg, L. (2009). How do socio-demographic and psychological factors relate to households’ direct and indirect energy use and savings? *Journal of Economic Psychology, 30*, 711-720.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes, 50,* 179-211.

Alborzi, F., Schmitz, A., & Stamminger, R. (2017). Effects of socio-demographic factors on laundry behaviours in Europe and their implications on sustainability. *International Journal of Consumer Studies, 41*, 671-684.

Almirall, E., Lee, M. & Wareham, J. (2012). Mapping living labs in the landscape of innovation methodologies. Technology Innovation Management Review, 2(9), 12–18.

Belaïd, F., & Garcia, T. (2016). Understanding the spectrum of residential energy-saving behaviours: French evidence using disaggregated data. *Energy Economics, 57*, 204-214.

Brandon, G., & Lewis, A. (1999). Reducing household energy consumption: A qualitative and quantitative field study. *Journal of Environmental Psychology, 19,* 75-85.

Brelih N. (2013). Thermal and acoustic comfort requirements in European standards and national regulations. *Federation of European Heating, Ventilation and Air Conditioning Associations (REHVA) Journal*. March 2013, 16-19.

Clayton, S., Devine-Wright, P., Swim, J., Bonnes, M., Steg, L., Whitmarsh, L., Carrico, A., (2016). Expanding the role for psychology in addressing environmental challenges. *American Psychologist, 71*, 199-215.

Druckman, A., Jackson, T. (2016). Understanding Households as Drivers of Carbon Emissions. In: Clift R., Druckman A. (Eds.) *Taking Stock of Industrial Ecology* (pp. 181-203). Cham: Springer.

Eurostat (2018). Available at https://ec.europa.eu/eurostat/statistics-explained/index.php/Energy_consumption_in_households. Last visited 18.10.2019.

Gram-Hanssen, K (2010) Standby consumption in households analysed with a practice theory approach. *Journal of Industrial Ecology, 14*, 150–165.

Harries, T., Iskandarova, M., Genus, A. (2019). ENERGISE Living Lab country report - United Kingdom. ENERGISE European Network for Research. Good Practice and Innovation for Sustainable Energy. Available at http://www.energise-project.eu/publications

Heiskanen, E., Matschoss, K., Laakso, S., Apajalahti, L. (2019a). A critical review of energy behaviour change: The influence of context. In Lopes, M., Henggeler Antunes, C., Janda, K. B. (Eds) *Energy and Behaviour. Towards a Low Carbon Future.* Academic Press.

Heiskanen, E., Laakso, S., Apajalahti, E.L., Matschoss, K. (2019b). ENERGISE Living Lab country report - Finland. ENERGISE European Network for Research. Good Practice and Innovation for Sustainable Energy. Available at http://www.energise-project.eu/publications

Heiskanen, E., Laakso, S., Matschoss, K., Backhaus, J., Goggins, G., Vadovics, E. (2018a). Designing real-world laboratories for the reduction of residential energy use: Articulating theories of change. *GAIA - Ecological Perspectives for Science and Society, 27*, 60-67.

Heiskanen et al. (2018b). ENERGISE Living Lab evaluation and assessment manual. ENERGISE European Network for Research. Good Practice and Innovation for Sustainable Energy. Deliverable No. 3.5. Available at http://www.energise-project.eu/publications

Jensen et al (2017). Catalogue of existing good practice examples of programmes and interventions. ENERGISE – European Network for Research, Good Practice and

Innovation for Sustainable Energy, Deliverable No 2.1. Available at http://www.energise-project.eu/publications

Laakso et al. (2019). Online tools and user community for scaling up ENERGISE Living Labs. ENERGISE – European Network for Research, Good Practice and Innovation for Sustainable Energy, Deliverable No. 3.6. Available at http://www.energise-project.eu/publications

Laakso, S. & Heiskanen, E. (2017). ENERGISE Good Practice Report: Capturing Cross-cultural Interventions. ENERGISE European Network for Research. Good Practice and Innovation for Sustainable Energy. Deliverable No. 3.1. Available at http://www.energise-project.eu/publications

Maréchal, K. (2010). Not irrational but habitual: The importance of “behavioural lock-in” in energy consumption. *Ecological Economics, 69,* 1104-1114.

Matschoss, K., Kajoskoski, T., Laakso, S., Apajalahti, E.-L., Heiskanen, E. & Luomaniemi, V. (approved for publishing with minor changes). Kestäviin energiakäytäntöihin - yksin vai yhdessä?. Kulutustutkimus.Nyt.

Morren, M. H., & Grinstein, A. (2016). Explaining Environmental Behavior across Borders: A Meta-Analysis. *Journal of Environmental Psychology*, *47,* 91-106.

Newton, P. & Meyer, D. (2013). Exploring the attitudes-action gap in household resource consumption: Does "environmental lifestyle" segmentation align with consumer behaviour? *Sustainability. 5*, 1211-1233.

Nummenmaa, L. (2004). *Käyttäytymistieteiden tilastolliset menetelmät*. Helsinki: Tammi.

Outcault, S., Sanguinetti, A., & Pritoni, M. (2018). Using social dynamics to explain uptake in energy saving measures: Lessons from space conditioning interventions in Japan and California. *Energy Research & Social Science, 45,* 276-286.

Pothitou, M., Varga, L., Kolios, A. J., & Gu, S. (2017). Linking energy behaviour, attitude and habits with environmental predisposition and knowledge. *International Journal of Sustainable Energy, 36*, 398-414.

Pothitou, M., Kolios, A. J., Varga, L., & Gu, S. (2014). A framework for targeting household energy savings through habitual behavioural change. *International Journal of Sustainable* Energy, 35, 686-700.

Rau, H. and Grealis, E. (2017). Everyday practices, cultural conventions and energy use: Researching new opportunities for reducing domestic energy use in Europe. ENERGISE –European Network for Research. Good Practice and Innovation for Sustainable Energy. Deliverable 1.2. Available at http://www.energise-project.eu/publications

Reckwitz, A. (2002). Toward a theory of social practices: A development in culturalist theorizing. *European Journal of Social Theory, 5*, 243-263.

Sahakian, M., Wallenborn, G. and Godin, L. (2019). Report on the analysis of ENERGISE Living Labs data across all eight participating countries. ENERGISE – European Network for Research, Good Practice and Innovation for Sustainable Energy, Grant Agreement No. 727642. Deliverable No. 5.2. Available at http://www.energise-project.eu/publications

Sahakian, M. and Naef, P. (2019). Overview of collective conventions, governing frameworks and material systems: across eight European countries. ENERGISE – European Network for Research, Good Practice and Innovation for Sustainable Energy, Grant Agreement No. 727642, Deliverable No. 5.1. Available at http://www.energise-project.eu/publications

Šćepanović, S., Warnier, M., & Nurminen, J. K. (2017). The role of context in residential energy interventions: A meta review. *Renewable and Sustainable Energy Reviews, 77*, 1146-1168.

Schliwa, S., Evans, J., McCormick, K. and Voytenko, Y. (2015). Living Labs and Sustainability Transitions – Assessing the Impact of Urban Experimentation. Paper presented at 'Innovations in Climate Governance', Helsinki, 12-13th March.

Schmitz, A. & Stamminger, R. (2014). Usage behaviour and related energy consumption of European consumers for washing and drying. *Energy Efficiency*, 7. 937-954.

Shove, E. (2003). *Comfort, cleanliness and convenience: The social organization of normality*. Oxford: New York: BERG.

Shove, E., Pantzar, M., & Watson, M. (2012). *The dynamics of social practice: Everyday life and how it changes.* Los Angeles: SAGE.

Stephenson, J., Barton, B., Carrington, G., Doering, A., Ford, R., Hopkins, D.,… Wooliscroft, B. (2015). The energy cultures framework: Exploring the role of norms, practices and material culture in shaping energy behaviour in New Zealand. *Energy Research & Social Science, 7,* 117-123.

Stephenson, J., Barton, B., Carrington, G., Gnoth, D., Lawson, R., & Thorsnes, P. (2010). Energy cultures: A framework for understanding energy behaviours. *Energy policy, 38*, 6120-6129.

Strengers, Y., Nicholls, L., & Maller, C. (2016). Curious energy consumers: Humans and nonhumans in assemblages of household practice. *Journal of Consumer Culture, 16,* 761–780.

Vadovics, E. and Goggins, G. (Eds.) (2019). ENERGISE Living Labs – Methodology, Experience and Lessons Learned. ENERGISE – European Network for Research, Good Practice and Innovation for Sustainable Energy, Deliverable No. 7.12. Available at http://www.energise-project.eu/publications

Vávra, J., Peters V., Craig T. & Cudlínová E. (2015). What shapes the temperatures of living rooms in three European regions? *Socialni Studia, 12,* 135-158.

Vogt, W. P. (2007). *Quantitative research methods for professionals*. Boston (Mass.): Pearson/Allyn and Bacon.

Warde, A. (2005). Consumption and theories of practice. *Journal of Consumer Culture, 5,* 131-153.

Winther, T., & Bell, S. (2017). Domesticating in home displays in selected British and Norwegian households. *Science & Technology Studies, 31*, 19-38.